THE PREVENTION OF MALARIA
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BY SIR RONALD ROSS,

WITH CONTRIBUTIONS BY

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JOHN MURRAY, ALBEMARLE STREET, W.

1911
Malaria fever is perhaps the most important of human diseases. Though it is not often directly fatal, its wide prevalence in almost all warm climates produces in the aggregate an enormous amount of sickness and mortality. In India alone it has been officially estimated to cause a mean annual death-rate of five per thousand; that is, to kill every year on the average 1,530,000 persons—a population equal to that of a great city. This is more than the mortality of plague at its height or of cholera and dysentery combined. The total amount of sickness due to it is incalculable, but may be put by a rough estimate at between a quarter and a half the total sickness in many tropical countries. Often all the children and most of the adults are infected by it. Unlike many epidemic diseases it is not transient, but remains for ever in the areas which it has once invaded. It tends to abound most in the most fertile countries, and at the season most suitable for agriculture. Very malarious places cannot be prosperous; the wealthy shun them; those who remain are too sickly for hard work; and such localities often end by being deserted by all save a few miserable inhabitants. Malaria is the great enemy of the explorer, the missionary, the planter, the merchant, the farmer, the soldier, the
RELATIVE administrator, the village and the poor; and has, I believe, profoundly modified the world's history by tending to render the whole of the tropics comparatively unsuitable for the full development of civilization. It is essentially a political disease—one which affects the welfare of whole countries; and the prevention of it should therefore be an important branch of public administration. For the State as for the individual, health is, the first postulate of prosperity. And prosperity should be the first object of scientific government.

Fortunately, as oft remarked, malaria is of all diseases the one regarding which we possess perhaps the fullest knowledge. We know the cause of it and the manner in which it is spread. We know a specific cure for it, and several efficient methods of prevention. It is our own fault then if we do not reduce it as much as possible.

The literature of the subject dates back for more than two thousand years. To write a complete book on malaria, including references to all that has been worthily said or done in connection with it, would be a gigantic task. The history, the symptoms, the pathology and the treatment would fill several volumes; a long essay could be written on the parasites; an entomological work on their carriers; and a full account of the laws of diffusion, of the local distribution, of the preventive measures, and of the numerous preventive campaigns which have been conducted since the time of the ancients, would of itself occupy many hundreds of pages. But the task would be largely an unnecessary one, because we already possess many good books on
the medical, parasitological and entomological aspects of the subject.

Regarding prevention, however, especially in the light of the great developments which followed the discoveries of twelve years ago, there is much need for yet another work. Though certainly based upon biological knowledge, this part of the subject presents also its own problems for solution. The diffusion of disease is a theme which requires exact, and indeed mathematical analysis; and the art of controlling it belongs, not only to the medical man, the parasitologist, and the entomologist, but even more to the experienced hygienist, the engineer, the administrative officer and the statesman.

On considering how best to meet the demand, I concluded that the only satisfactory way was to collect in one volume the thoughts and observations of the able men who have themselves worked in this laborious field, or who are in the best position to furnish the required information; and my warmest thanks are due to those who have given me so much of their valuable time and labour. My own part consisted merely in attempting to compile a preliminary analysis of the general problems and difficulties before us.

Some readers will perhaps be surprised when they fail to find in a book on the prevention of malaria any description either of the parasites and their carriers, or of the necessary technique. But in these days almost every medical man in the tropics, at least any one likely to be entrusted with the charge of anti-malaria work, is sure to be already familiar with these details.
over, the present volume should be written largely for the use of readers who are neither medical men nor zoologists, but who may be called upon to deal with the administrative side of the subject; and minute technicalities would be as useless to them as they would be superfluous to the trained biologist. I have therefore determined to limit myself to matters which will, I hope, be useful to the advanced student without being unintelligible to any educated reader—that is, to a logical consideration of the broader (and often more neglected) principles of the subject.

An historical introduction is always necessary to give coherence to ideas; and I have taken the opportunity to write as complete and accurate a one as my space and knowledge permit of. The summary of facts which follows (taken from my report on Mauritius) may be useful in propagandism; the experimental inoculations of men by means of blood drawn from patients or infected Anophelines have been collected with care because of their fundamental importance in the modern theory of malaria; and I trust that these three first chapters will suffice to convince the busy Statesman that this theory has been based upon something more than mere conjecture.

In the chapters on the parasitic invasion of the individual and of the community, I have departed considerably from medical custom by laying much stress upon quantitative, or rather enumerative, ideas. We should distinguish between subscience, the mere study of objects, and science, the study of causes. Measurement is the very basis of science; and the neglect of
it and of logical deductions founded upon it are too common in biology. It is scarcely true to say that malarial fever is caused by a parasite and propagated by a mosquito; it can be caused only by many parasites and widely propagated only by many mosquitoes. The how many and the how many are at least as important as the bare facts. I am convinced that if more exact results are desired, pathology must in the future tend more toward exact enumerative methods. As for epidemiology, it is principally a mathematical subject—the rate of infection being given, the rate of infection depends upon laws like those which govern the diffusion of gases or heat; and ignorance of this has led to many wild statements regarding the spread and prevention of malaria. But the subject has yet to be developed, and Chapter V can approach it only in an elementary manner. Chapter VI is abbreviated owing to the details contained in the following one, to which it is largely introductory.

The contributions in Chapter VII are arranged geographically, as far as possible, and have been printed in the authors' words without modification. A useful index has been found impracticable; but a detailed table of contents is given at the end of the volume.

The omission of several important matters must be explained and apologized for. Some good campaigns have been left undescribed because I could not find reporters for them and failed in obtaining otherwise all the necessary particulars regarding them; not in any way because they should not have been included. A chapter on the local distribution and cost of malaria
would have been useful, and was attempted. The older books contain much on the former point; but the information given was based upon evidence which would scarcely satisfy us to-day, and accurate details could not be obtained without such long enquiry that I was forced to abandon the project entirely. Lastly, references to much good literature have been omitted or curtailed—not because such literature is of secondary importance, but because the object of the book is to present a general discussion of particular points rather than a complete record of all the known facts and hypotheses. But there is another reason for these omissions. Owing to grants recently given by the Advisory Committee for the Tropical Diseases Research Fund (collected by the British Colonial Office), we are now preparing in Liverpool, not only for new researches, but for an exhaustive descriptive bibliography of malaria, in which, I trust, all the literature both of general and of local interest will be collated and compared. Indeed before long the whole of this immense subject will perhaps be dealt with in the only adequate manner possible—that is, by a special Bureau appointed for the study of it; and this book is intended to be a necessary preliminary to that work.

I hope that most of the matter contained in it will be of use to any one who proposes to undertake a genuine campaign against malaria. For this purpose we require a knowledge, not only of biological technics and of the various possible preventive measures, but also of the broad principles of sanitary statesmanship. The prevention of malaria on a large scale is a great economical
as well as a great humanitarian undertaking. A genuine
campaign does not consist merely in the formation of
inexpert committees, the passing of ordinances for the
screening of water-buts, and the issue of wise advice
to the public. To be permanently and economically
successful, it must always be a permanent concern of
the State, requiring careful measurements of the amount
of sickness present, a nice appreciation of the measures
most suitable for the locality; exact estimates of their
cost compared with the cost of the disease; a well-
considered organisation, and, above all, a fixed deter-
mination to succeed.

The world requires at least ten years to understand
a new idea, however important or simple it may be.
The mosquito theorem of malaria was at first ridiculed,
and its application to the saving of human life treated
with neglect, jealousy and opposition. But now, owing
to the labours of many of those who have contributed
to this volume, and of all of those who have so long
and so patiently studied the subject, we are assured
of final success. To them and to the memory of them
this book is dedicated; but we must not rest content
until the principles so well established by them are
followed in every civilised country of the world. I
hope, too, that mosquito reduction will before long be
undertaken in most of the towns in the tropics, whether
they are malarious or not.

RONALD ROSS.
P.S.—To the second edition of this work I have added in section 65 some notes on malaria prevention in India, and on some historical points; and also, at the end of the book, a more complete study of the mathematical part of the subject.

R. Ross.

1st June 1892.
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THE PREVENTION OF MALARIA

CHAPTER 1

HISTORY

1. Ancient Times.—Dr Richard Caton has kindly tried to ascertain for me whether there are any distinct references to malaria in the ancient Egyptian writings; but informs me that he knows of none in the medical papyri or temple inscriptions, and that Dr J. H. Walker confirms this statement. It should be noted that Strabo (first century B.C.) observed that Alexandria, in spite of marshes in the neighbourhood, was free from malaria in his time; and even at the present day the disease does not abound in Egypt as much as might be expected.

In Greece and Italy, however, malaria has been well known for more than two thousand years; and Greek and Italian authors have collected many references to it in old writings. Recently Mr W. H. S. Jones has given us a laborious and exhaustive study of the subject made in the light of our present knowledge [1907, 1909].

The first-named authors have always taught that the disease was very prevalent in those countries from the first; but Mr Jones, following a tentative suggestion of mine, gives many reasons in favour of the view that it may have entered them from without during historical times, and may subsequently have exerted considerable influence upon their civilization. Thus, there are few references to it in the earliest literature,
but many in later writings. Homer (say 1100 B.C.) mentions what might be malaria, but only once (Iliad, xxii. 31); and Hesiod (say 735 B.C.) though he lived at Orchomenos on the shore of Lake Kopais, now intensely malarious, and dealt with rural subjects, makes no clear reference to it. Theognis (say 550 B.C.) probably mentions it, and Herodotus (494 B.C.) possibly so. Jones infers from the medical writings attributed to Hippocrates that paludism was known in the medical schools before his birth (about 460 B.C.), and from the Wasp, of Aristophanes (425 B.C.) that it "was attracting particular attention at Athens" at that time. About 419-410 B.C. the Athenians erected on the Acropolis a statue to Athena Hygieia, and introduced the worship of Asclepius, tending to show that "ill health was distinctly on the increase"; and after this "references to fevers became much more numerous," and malaria probably very common in Greece. He describes accurately and fully the effect which this must have had on its civilization. 

Apart from the literature, I am strongly of the opinion, based upon many considerations, that malaria could scarcely have been very rife in Greece before the height of its prosperity. The people were too vigorous and warlike. The gymnastic training of youths could scarcely have been possible if enlargement of the spleen had been very prevalent. The figures on the tombstones, though evidently idealized, do not suggest to my own medical apprehension anything resembling a malarious race; and the open-air life and ceremonies do not suggest a malarious country. The ancient flourishing population round Lake Kopais, for example, would have been simply impossible if the disease had been as rife then as it is now. It is now very rife there and in most of the Grecian villages; and there must have been a time when the change took place. Quite possibly it was introduced about the fifth century before

1 In 1906 I found that twenty out of forty children at Orchomenos were suffering from enlarged spleens in June, that is before the malaria season.
ANCIENT TIMES

Christ by soldiers or slaves from abroad, as it was certainly introduced into Mauritius in 1866 (section 30 (21)). Spreading gradually up the valleys, it would have tended to destroy rural prosperity to drive the people into the healthier towns (as in Mauritius), and, assisted by other causes, to sap the vigour and physique of the race [Ross, 1906]. It is well known that the ancient Greeks recognised the quartan, tertian, quotidian and semiterterian (probably malignant tertian) varieties of paludism, and many of its accidents; and were acquainted with its seasonal and local variability, and, above all, with its frequent prevalence near marshes. This last point is most germane to our present part of the subject.

Thus there is an old story that Empedocles of Agrigentum (say 550 B.C.) delivered Selinus (in Sicily) from a plague by draining its marshes, or by turning two rivers into them”—that he was able, as Matthew Arnold says, to

"Chase to sweet airs the breath of poisonous streams."

Doubt has of course been thrown on the story; but whether it is true or not matters little. The mere fact that such a tale was told proves that the Greeks, even at an early date, had become in some way aware that marshes tend to generate sickness, and, still more important, that by drainage or other treatment this may be prevented. There are many passages connecting malaria with marshes. Thus as already stated Strabo (first century B.C.) says that Alexandria, in spite of its site, was free from marsh-fever even in his time. "It is 0 be inferred from this," Mr. Jones says, "that damp places were generally known to be unhealthy, so that exceptions to the rule were noticed by observers as remarkable phenomena." Hippocrates (Airs, Waters, Places) noticed that those who live in low, meadowy and hot districts tend to be neither tall or well-built, but stout, fleshy, dark-haired, dark-coloured, bilious, and wanting in courage and endurance.

For ancient Italy we have a similar theory, namely, that
references to paludism are scanty in the earlier writers, but
very abundant in the later ones. Mr Jones notices, both for
Greece and Italy, that many of the most ancient settlements
appear to have been made on sites which are now pathetically
—suggesting that they were not so unhealthy when they were
first selected. Professor R. C. Bosanquet tells me that some
of the oldest settlements in Crete, made during the wonderful
ancient civilisation of that country thousands of years before
Christ, were situated at spots which are now intensely malarious.
Many areas round Rome, now scarcely habitable, were the
homes of great and prosperous peoples in the prehistoric
period, and were later full of the country villas of rich Romans.

Those who consider that malaria was always very prevalent
in ancient Greece and Rome cite legends such as that of the
destruction of the Lernean Hydra by Hercules—the Hydra
being supposed to be symbolic of malaria. Lerna is a marshy
district in Greece, and the Hydra was fabled to inhabit the
marshes and to ravage the country round it. It is possible,
however, that the fable refers merely to the drainage of the
swamps for agricultural purposes. In Italy there was a vast
and very old system of soil-drainage by canali, probably
constructed by the Etruscans; and some have suggested that
this drainage was carried out against malaria, and that it
enabled the ancients to build villas at spots now deadly.
Here, again, the object of the drainage was more probably
agricultural. I should like to believe that it was a sanitary
drainage, but find difficulty in doing so. Drainage against
malaria must obviously be an urban and not a rural measure.
The cost of draining all the country round Rome merely for
sanitary purposes would have depleted the sanitary budget
even of the logical ancients. Mr Jones's view appears the more
probable—namely that the disease was possibly introduced
at the time of the first foreign expansions, both in Greece and
Italy, and that it gradually became intensified owing to the

1 See also F. Genovese [1909].
cause described in sections 30 (20). North [1896] ascribes the intensification to rural depopulation—due to wars or to economical changes. I think it more probable that the malaria produced, or helped to produce, the rural depopulation; and we now have the living picture of the process before our eyes in Mauritius. Possibly also the disease has always had a tendency to eliminate or repel the fair strain of blood from the lighter leaving the darker southern strains predominant. But the effect in Italy was probably less than in Greece, owing to the much smaller proportion of malarious area in the former.

Of course the Roman writers, both medical and non-medical, were acquainted with the leading facts about paludism mentioned above. The erudite Varro (116-28 B.C.) says in his *De Re Rustica* : "Animadvertendum etiam si quo erunt loca palustria, et propter eandem causam, et quod crescent animalia quandam minuta, quae non passunt oculi consequi, et per aera intus in corpus, per os ac nares perveniunt et difficiles efficiunt marbas"—that in marshes there are animals too small to be seen, but which enter the mouth and nostrils and cause troublesome diseases. Other famous passages are from Columella (about the first century B.C.), who says that bogs breed insects armed with stings, and pestilent swimming and creeping things, from which come obscure diseases. Here we have malaria connected not only with the marsh, but with insects or germs bred in the marsh. Cicero and Seneca say that paludism depopulated certain districts. Mr Robert Glaedstone and Mr Jones have kindly called my attention to several passages referring to *mosquitos aequo*, called *conopum* by the Romans, after the Greeks (our word canopy). Herodotus first noted with surprise the use of them in Egypt; and they are referred to later in Varro (*De Re Rustica* 2, 20, 8), Horace (*Epod, 9, 45*), Propertius (*Epid. 9, 45*), *Juv. (6, 80)*, and *Paulus Silentiarius (Anthologia Palatina)*. Horace says, "And among the military standards, oh, shame! the son "sons a
mosquito curtain;" and Propertius calls these nets *foda* (fool or disgraceful). Evidently the ancients felt towards them as do many of our own more manly colonists who prefer annoyance and even sickness to disgrace! But Propertius Silvanus thought that they were useful for a post-prandial siesta in order to save the slaves the trouble of using a fly-flapper. Virgil said that women, lately confined, spent a number of days in them; and Juvenal said that they were used to cover the cradles of the rich and noble.

On the 6th February 1905, Sir Henry Blake, Governor of Ceylon, called the attention of the Ceylon Branch of the Royal Asiatic Society to the fact that certain ancient Sinhalese writers, who lived certainly more than 1300 years ago, had connected fever with mosquitoes. The original authority appears to be Susruta, in the chapter on Insects which forms the last chapter of his book on Poisons. He says that there are five kinds of mosquitoes, one of which "produces the same symptoms as deadly insects." Jolly, however, discussed the subject (1905), and thinks that Susruta was merely referring to the irritation caused by the bites. He attributed malaria, Jolly says, to derangement of the humours. Personally, so far as I can judge, I doubt whether these writers ever really connected malaria, even in imagination, with the insects.

2. Early Modern Times.—Little was added to our knowledge during the next thousand years; but about 1635 the inestimable boon of *Cinchona bark* was introduced into Europe. The Countess d'El Cinchon, wife of the Viceroy of Peru, had been cured of fever by means of it in that country, where it had been discovered by the Indians near Laxa (?); and she was wise enough to send it home to Europe. The use of it, after many checks, gradually spread; and in 1820 Pelletier

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3 I see nothing little about malaria in early days in America; it according to a suggestive paper by C. Elton, the disease was probably introduced there from Europe, but as the common sheep-tick with *uropile* (1805).
and Caventou extracted the alkaloid quinine from it. But the discovery of this specific has not only proved to be a blessing for the treatment of untold millions of human beings, but also enabled Morton [1697] and Torti [1753] to separate the malarial fevers, which are cured by it, from those upon which it has no influence, and by this means to differentiate and study the symptoms of the former. Morton also recalled the hypothesis of the marsh; and this was amplified by Lancisi, who repeated the views of Varro and Columella in greater detail in his book *De natis paludum officiis*. He stated that fevers disappear after drainage, and attributed the poison—either to inorganic or organic emanations from the marsh. He studied mosquitoes, and even suggested inoculation by them as a possible means of infection—though he also thought that their larvae foul drinking water [1757].

It is now apparent that the world had been gradually becoming aware during centuries of the paludic nature of malarial fevers, not by direct experiment or even by investigation, but by a kind of subconscious experience based on public observations. In Italy especially, where of all civilised countries the disease was most prevalent, this process was most apparent—so much so that, as North describes [1896], the peasantry can often tell at sight which localities are likely to be "malarious." More than this, by similar general observation, the good effect of assainment of marshes had become equally notorious there. Thus, as early as 1667, Dool wrote a work called *De Restituenda Substitutore Agri Romani*; and references to a succession of works carried out on this principle, which I now call the principle of Mosquito Reduction, are given by Celi [1904]. At the same time efforts were made by many observers, such as Morton, Lancisi, Lind, Pringle, to explain the paludic connection; and these resulted in the formation of the hypothesis of the paludic miasma. This was supposed to be some kind of infecting emanation from stagnant water, either chemical, or as Lancisi suggested, organic; but in no
cases, apparently, were experiments made to test the point. Later, when it was observed that malaria may sometimes occur where there is no marsh, the hypothesis of the paludic miasma was extended to that of the telluric miasma, according to which the poison exists not only in marshes but anywhere in suitable soil, from which it rises at night or when the soil is disturbed. This speculation, for it is nothing more, is not quite dead even yet, though the observation which originated it is explained otherwise. The word “malaria” (mala = evil, air) is derived from it.

3. Discovery of the Parasites. - Last century, however, pathological science was no longer content with mere guesses at the truth, but began to demand strict microscopical and experimental evidence. Applied to paludism, this method gave an early reward. In 1847, H. Meckel discovered innumerable black granules in the blood of an insane patient; and the discovery was subsequently confirmed and amplified by Hahnemann, Virchow, Haeckel, Planer and Arnstein—the granules now being known under the name of the paludic pigment, or malaria, or hematozoon (Sambon). For a long time they were thought to be due to a chemical action of the paludic miasma on the red cells of the blood.

About the same time many laborious attempts were made to discover some animal or vegetable organism which lives in marshes and produces paludism. As long ago as 1846 Rasori (cited by S. Calandrucio) made an extraordinary prediction on this subject. “For many years,” he said, “I have held the opinion that the intermittent fevers are produced by parasites that cause the successive paroxysms of fever by their reproduction, which occurs periodically more or less rapidly according to their species”—and this has proved to be exactly true. Many writers attributed the disease to various marsh-growing vegetables. In 1862 Salisbury in particular, after considerable...
study, blamed a kind of Palaeola; and after 1878, a number of Italian workers, Lanzi and Terrigi, Edwin Klebs and C. Tommasi-Crudeli, thought that they had actually incriminated certain fungi or bacteria, which they said swarm in malarious places, occur in the blood, produce spores before each paroxysm of fever, and cause similar infections in animals. These findings were even confirmed by Marchiafava and other Italians, but have not been completely discredited.

In 1878, however, A. Laveran commenced his studies of the subject at Bens in Algeria, by following up the granules of pigment, already referred to, in the blood of living patients. He was struck by the fact that they were frequently contained within cells possessing active amoeboid movements; and, finally, on the 6th November 1880, at Constantine, he detected the microgametes issuing from the male cell. Though at the time he did not know the nature of this phenomenon, it convinced him that he was dealing with a living parasite of the human red corpuscles. In fact the black granules are merely the excrementitious matter produced by the parasites from the substance of the red cells, and contained within their bodies, or released in the tissues of the host.

About the same time C. Gerhardt proved that healthy persons can be infected by the inoculation of blood of patients suffering from paludism (1884). His experiments were afterwards verified by many workers, and demonstrate (apart from the microscopical discovery of the parasites) that the disease is not due to any gaseous emanation from marshes, but is a true infection by some living virus.

In 1886 and subsequently, C. Golgi, who was favourably situated in Pavia for the work, showed clearly that the parasites...
reproduce by simultaneous sporulation; that the febrile paroxysm in the patient commences at the moment when these spores are liberated (just as Rasouli had divined); and that the parasites of quartan and mild tertian fever are morphologically different (1886). A little later, Canalis, and Marchialava and Celli discovered similar facts regarding the malignant parasites, and showed that they differ from the quartan and mild tertian parasites; and Marchialava and Bignami suggested that they are of two varieties, the malignant tertian and the quotidian. In 1885 Danilewsky discovered similar parasites in birds and several other animals; and subsequently Marchialava, Celli, Bignami, Mantalberg and others, made many careful studies of the parasites, and of their effects in human beings; Romanowsky found the proper way to stain them; and many observers verified these researches in various parts of the world—the literature amounting to some hundreds of publications.

4. Speculations regarding the Mode of Infection.—But the question now arose—an all-important question in connection with the prevention of the disease—How do these parasites manage to effect an entry into the blood of men and animals? Most observers, remembering that the disease often abounds in the neighbourhood of marshes, assumed at once that Laveran’s parasites must be capable of living in a changed form in stagnant water; and some actually sought them there. Thus Grassi and Calandruccio suggested that a free living amoeba is really the external stage of the organism. On the other hand, experiments to infect healthy persons by water from marshes, made by Marchialava and Celli (1885), Martini (1895), and especially Agnone Sarti (1896) failed entirely. Zeri gave marsh water to nine persons to drink in doses from 1½ to 3 litres a day for a number of days, to another five persons he gave the water by clyster; and to sixteen by spray inhalation—yet no paludism followed. Like all negative results, his are not absolutely conclusive—since the failure may have been due to some unforeseen
DISCOVERY OF METAXENY

condition absent from the experiments; but his paper is too important to have been forgotten as much as it has been.

Before describing my own Indian researches which commenced at this point, it is necessary to survey our general parasitological knowledge, together with the state of thought regarding malaria, at the time. Discoveries concerning Laveran's bodies, which are animal and not vegetable organisms, have a line of descent from previous discoveries concerning animal parasitology, and not directly from bacteriology.

Many of the large animal parasites of man and animals have been known to us from antiquity, but until the beginning of the eighteenth century, were supposed, like other low forms of life, to be created in each host by "spontaneous generation." Even long after Redi (1668) proved that this hypothesis did not hold for certain insects, it was still supposed to apply to the parasites. Gradually, however, large numbers of the latter were discovered, and Faust put forward the view that they originate, like other animals, from eggs, which escape from an infected person or animals, and are by chance swallowed by another host. Such a history is, in fact, quite correct for many parasites; but in 1790 Abildgaard made the remarkable discovery, by experiment, that the parasites, called Bothriocephalus solidus and Ligula, inhabit for a part of their lives certain fish, and reach maturity only in certain water-fowl which happen to swallow the infected fish. This appears to have been the first (and only instance of the wonderful process of metaxeny) of change of host. The idea was lost sight of for years until Eschricht in 1841, and Steinmann in his famous work on the alternation of generations of Trematodes (1842), recalled it. It was finally established for Cestodes by F. Kirchenmeister, physician to the Duke of Saxe Meiningen, in 1851-1853, by means of direct experimental feeding methods first used by him. Metaxenous

1 I use this word on the authority of Dr. Bary, who employs the incorrect form "metaxenous" in the above sense—see his book on Fungi, Mycetozoa, and Bacteria. Vienna: Courtenen Press, 1843, p. 307.
parasites are those which spend part of their life in one kind of animal, and the rest of it in another—generally the early part of their existence in one host, and the mature sexual part of it in another host which preys upon the first one, as in the rabbit and the dog, the mouse and the cat, swine and men, and so on. Moreover, he proved that the eggs or young of the mature parasites are able to pass back again into individuals of the first species of host, from which they are again transferred to the second species of host—and so on, ad infinitum.

This great discovery, which may almost be called the basis of modern parasitology, was rapidly verified by Kiihnknopff and Leuckart for many parasites. At first it was applied to those of the higher animals; but before 1858 Leuckart discovered that the Nematoe worm, Caecilianus elegans of the perch develops in the little aquatic Arthropod called Cyclops, or the Water Flea. Next, perceiving the resemblance of this worm to the famous Filaria medinensis, or Guinea Worm of man, he suggested in the same year (1858) to the young Russian naturalist and traveller, Fedchenko, that the latter parasite may also pass a stage of its life in a Cyclops. The Guinea Worm lives under the human skin, and emits its young through an ulcer which it produces in the integument—the young next finding their way into water. A few months later Fedchenko proved by experiments in Turkestany that Leuckart was right. He watched the development of the embryos in the Cyclops; but did not complete the cycle by infecting men from the latter. He supposed, however, that men become infected by accidentally swallowing infected Cyclops in drinking water.1

1 For an account of this discovery see R. Leuckart, Die Menschlichen Parasiten, 1876, vol. ii. p. 704. As it is an extremely important discovery, I have been at considerable pains to ascertain the exact dates. It will scarcely be believed, but Leuckart's elongated worms are difficult to obtain in this country. I am indebted to Dr. R. T. Leiper for having supplied the specimens. The facts appear to be as follows: In 1858 Leuckart (when at Naples) suggested the idea to Fedchenko, who went there immediately and examined the Cyclops. He first published his account of the development of Caecilianus in Cyclops, but merely hinted at the idea that F. medinensis has a similar development, without mentioning Cyclops as the possible second host. In 1859 Fedchenko seems to have obtained from
TRANSMISSION OF Filariae

In 1868 another important case was discovered by Leuckart and Melnikoff in Leuckart's laboratory. They found that the young of Dipylidium caninum (Tonina caninum), a parasite of dogs and cats, develops in the dog-lice—this being, I believe, the first case in which a parasite of a mammal was found to be transferable by any kind of vermin which feeds on that mammal. The great credit due to Leuckart in connection with this discovery has been much overlooked of late.

Filaria bancrofti, a human parasite, was discovered in the adult form by Bancroft in 1876, though its embryos had been 'seen' by Domasquay in 1863 in chylous fluid, and by Lewis in blood in 1872. In the Lancet, 12th January 1876, Cobbold mentions a suggestion of Bancroft, dated the 20th April 1877, that the worm (which is closely allied to F. medinensis, and noted to Cucullanus) might be carried by mosquitos. In 1877, P. Manson, in Amoy, China, came to the same conclusion, and on examining a number of mosquitos fed on a Chusanese whose blood contained the embryos, discovered that these develop in the tissues of the insects just as the embryos of F. medinensis develop in Cyclops. This was the first time that heteroxeny was found to occur with any parasite between man and mosquitos; but Manson did not observe the development of the embryos to a stage much more advanced than that observed by Egeschenko in Cyclops. He thought also that mosquitos die on the surface of water a few days after feeding on blood; and that the partially developed embryos then liberate themselves from the dead insects, and, after swimming free in the water, are swallowed by human beings. But he did not prove this; and indeed, in 1900, G. C. Low and N. P. James, acting on the evident suggestions of my work on

Leuckart, and to have published his paper in Russian, describing the development of F. medinensis in Cyclops. The fact, however, must be taken as the date of publication of the discovery. A. J. Jacobi, Leuckart's biographer, can give me no further information.

malaria, made observations which lead us to think that the embryos return to human beings through the insect's proboscis. By his detailed studies, however, Manson has built up most of our present knowledge on the subject of filarial disease in man.

It should be noted here that all those examples of metaxeny apply only to the higher parasites, the Helminths or Worms, and that in some of the cases, including those of Fekushenko and Manson, the life-cycle had been by no means completely ascertained—so much so that many doubted whether the observed development of the embryos in Cyclops and Culex could be looked upon as a genuine stage of metaxeny. But the bodies discovered by Laveran belong to a still lower, in fact to the lowest, class of animals—the Unicellular ones. Though many organisms of this class—amoebas, gregarines, coccids, trypanosomes—have been discovered in various animals, yet up to 1889 not one of them had been proved to be metaxenous. During this year, however, a remarkable discovery was made by Theobald Smith and F. L. Kilborne in America in connection with the disease called Texas cattle-fever. For a long time the farmers had thought that it is caused by certain cattle-ticks. Smith and Kilborne now showed that the disease is due to minute parasites of the red corpuscles, akin to the parasites of malaria, but not belonging to the same group, called *Piroplasma influens*, and that they are inoculated in some way into healthy cattle by the bites of young ticks born from a parent tick which has fed upon a diseased one. This fact was conclusively proved by direct experiment, and suggested that these *Piroplasmae*, which are unicellular animals, might also be metaxenous like so many of the higher parasites. But the observers failed in following out microscopically the life-history of the *Piroplasmae* in the ticks, and therefore did not actually prove any alternate generation in them.  

Meantime, however, there had been many vague conjectures to the effect that several diseases may be produced by biting vermin. Thus, as just mentioned, American farmers had long thought that Texas cattle-fever is carried by cattle-ticks. Many travellers also related that African natives ascribed a peculiar stiffness to the bites of another kind of tick; and others said that the deadly nagana of cattle in parts of Africa is probably due to the bites of the tsetse fly. And similar speculations connecting both yellow fever and malaria with mosquitoes had long been rife. Generally derided at the time, these views were speedily forgotten; and it is only of late that many of them have been resuscitated and discussed as instructive relics of the past. It will, I think, interest the reader to follow the gradual development of our knowledge of this important subject.

Page already mentioned the curious utterances of Varro, Columella, the ancient Sinhalese books, and of Lancisi, regarding insects and fever. Nuttall [1899, p. 75] gives statements by Nuttig, Koch, Rubner, and myself, to the effect that the peasantry in Italy, Tyrol, East Africa, and Assam seemed to have vague ideas of the same kind. Dr R. H. Kennan informs me that he has found an old ordinance of Freetown, Sierra Leone, dated 1812, in which the inhabitants (mostly freed slaves) are enjoined to keep the road in front of their plots in good condition in order to prevent the formation of " stagnant pools which generate disease and mosquitos over the town."

In 1848, Dr Josiah Nott, of Mobile, Alabama, appears to have stated that both yellow fever and malaria may be transmitted by mosquitoes, and refers to the speculation as having been already advanced as regards malaria. In 1854, however, Louis-Daniel Beauperthuy, a French medical man, born in Guadeloupe in 1808, gave the hypothesis in greater detail [1854]. As a "travelling naturalist" for the Paris Museum in Venezuela, he studied both these diseases microscopically, and concluded that they are produced by a venemous fluid injected under the skin by mosquitoes, like the poison injected by snakes. Macanis, he...
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18, dangerous because of the mosquitoes breeding in them, not because of their effluvia. He stated that several species of mosquitoes carry yellow fever, but mentioned especially "the mosquito which breeds in water" and again "the mosquito with legs striped with white," which we now know is really the agent. But Stegomyia calopus, which he mentions, is probably the correct form, with legs striped with white.

Stegompa calopus, which we now know is really the agent. He mentions no experiments in support of his opinions, which seem to be only ingenious speculations based upon general thought and observation.

In 1881, and subsequently, Charles Finlay of Havana, repeated a similar hypothesis, apparently independently of Nott and Beauprethuy [1881]. His views, however, differ in an important particular. While Beauprethuy seemed to think that mosquitoes originally obtain the disease-giving poison from the marsh in which they breed (and Varro, Columella, and Lancisi believed the same), Finlay held (regarding yellow fever) that they obtain it from sick persons. In other words, he thought that the insects simply convey it from patients to healthy persons. The proboscis of a mosquito which bites a patient becomes contaminated by germs in his blood; the germs multiply in the proboscis, and then enter the blood of any person whom the mosquito bites next—just as bacteria may be carried on a soiled surgical instrument from one person to another. He thought that an insect which had only just bitten a patient could convey the virus; but that the longer it lived after biting the patient the more the germs would multiply in its proboscis, and the larger the dose given to the healthy person would be. He also considered that the mosquito with striped legs (Stegomyia calopus) is the agent of yellow fever. He records some experiments, but they must have been very doubtful, since we now know that mosquitoes which have bitten a patient must live for no less than twelve days before they can infect a healthy person. Like Beauprethuy, he rightly conjectured the species of mosquito which carries yellow fever, and actually placed them in the hands of the men who ultimately solved the problem.
He was acquainted with Manson's researches on the development of *Filaria bancrofti* in mosquitoes.\(^1\)

In 1883 Dr A. F. A. King wrote an able paper on the subject in which he gives no less than nineteen reasons why mosquitoes are likely to carry paludism. These are:—

1. Both paludism and mosquitoes are connected with marshes;
2. They both require a temperature of over 60 degrees F.;
3. They are chiefly at festering points;
4. Abound most near the river and sea-coasts;
5. Have an affinity for dense foliage;
6. Can be screened off by trees;
7. Can be transported by winds;
8. Are encouraged by turning the soil;
9. Are affected by "breeds of water";
10. Are diminished by cultivation and settlement;
11. Keep near the surface of the ground;
12. Abound most at sunset;
13. And in the open;
14. Are destroyed by fires;
15. Are not so common in cities;
16. Are most prevalent in autumn;
17. Are arrested by mosquito nets;
18. Affect infants (which are generally protected by nets);
19. Are not so common in cities;

Like Beauperthuy, he held that the insects bring the poison from the marsh and inoculate it by their bites. He was acquainted with Manson's work, but not with Laveran's. His paper was speedily lost sight of, and was not resuscitated until my researches had cleared up the question.

About the same time Laveran suggested the same idea in a short sentence: "Do mosquitoes play the same role in paludism as in filariasis?" he said. "The thing is not impossible, and we must note that mosquitoes abound in all marshy places."

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\(^{1}\) For further details see the interesting book, *Mosquito or Men*, by my colleague, Dr Robert Boyle. John Murray, London, 1909.
Also about the same time, during his famous studies on cholera in India, R. Koch had the same notion; but he mentioned it only in his lectures to students [Nuttall, 1896, p. 77, and Ross 1905, p. 77].

Ten years later, and some years after I had commenced my studies of the subject, P. Manson supported the mosquito hypothesis in a rather short paper [1894]. But he added a new and a stronger argument to those already given: in the blood of man the parasites of malaria consist chiefly of forms which reproduce themselves indefinitely by spore formation; but in addition to these there are other forms which appear to possess no function in the human body, but which, shortly after the blood containing them is drawn from the patient’s finger, often emit long and actively motile filaments which may break away from the parent cell, and wriggle about rapidly in the fluid under the microscope. For a long time these bodies had been the subjects of discussion. Some observers, chiefly of the Italian school, held that they represent only the dying struggles of the parasite; others, including Laveran and Danilewsky, thought that they are really living bodies; and Mannaberg even suggested that they may be connected with the life-history of the parasites outside the human body—though he did not explain how this could be. Manson now offered an explanation. He thought that when a mosquito sucks the blood, these parasites enter its stomach with the blood, and there, in a few minutes, emit their motile filaments just as they do under the microscope. The motile filaments, he thought, were flagellated spores, which next pass through the walls of the mosquito’s stomach and take up their abode in its tissues, where they must develop further. Two years later he repeated this hypothesis [1896] with the assistance of my preliminary researches, but added some conjectures as to the future fate of the “flagellated spores.” He still thought that mosquitoes die on the surface of water a few days after laying their eggs in it. The malaria germs...
VARIOUS HYPOTHESES

might now escape from the dead insect into the water, with which they might be swallowed by men; or they might be blown about with the dust and be inhaled; and they might also be swallowed by mosquito larvae and so propagate themselves indefinitely in the insects, apart from man. Roughly, the life-history of Laveran's bodies was he thought, similar to that which he considered Filaria bancrofti to possess.

Months later A. Higami attacked Manson's views for several reasons [1926]. He refused to admit that mosquitoes can take the parasite from human beings, but supposed, conversely, that human beings take it from mosquitoes. In support of this he adduced some of the reasons previously given by King. Several other writers supported or opposed the hypothesis about the same time.

This is a short, but, I think, a fairly exact account of these hypotheses. The importance of speculations of this kind is apt to be either undervalued or overrated. Modern science does not look upon them with much favour unless those who publish them strive also to verify them. It is easy to sit at home and weave many hypotheses; but attempts to verify them generally demand endless labour, expense, self-sacrifice or even danger, and often fail, or, even if successful, win little reward. There were many before Columbus who imagined America; but between the dream and the reality an ocean had to be traversed. All the conjectures mentioned above have proved wrong in many particulars. Mosquitoes do not bring the virus from the marsh to the man, nor from the man to the marsh. The truth has proved to be far more wonderful than any hypothesis. It is curious that no one recognised the suggestion which should have been obtained from the phenomenon of metaxeny among some other parasites, namely, that the mosquitoes might carry the virus from man to man. I was driven to this in 1896-1897 just before the fact was revealed.

On the other hand, such speculations often serve a useful purpose by giving some direction to practical work. Thus
those connected with Texas cattle-fever, nagana, and tick-fever greatly limited the labour of research by suggesting the actual species of the alternative hosts, namely certain ticks and tsetse flies; and those of Beauperthuy and Finlay suggested the *Stegomyia culicoides* as the agent of yellow fever. With regard to paludism the earlier hypotheses, critically looked at, suggested nothing more than that there might possibly, or probably, be some connection between mosquitoes and the disease. Manson's idea regarding those forms of the parasites (gametocytes) which produce the malarial filaments (microgametes) was, however, more than a mere speculation—it was an induction based upon our general knowledge of parasites. As he said, these trophons must have some meaning and object. It was difficult to imagine that they could have any other object except to infect some suctorial animal—probably mosquitoes. But this idea led us no further; it gave us no clue as to how and where the parasites live in mosquitoes, how they return to man and infect him, and in which of the hundreds of species of mosquitoes they exist. It was only a glimmer in the darkness—but it was something. Obviously the truth could be obtained only by a long and determined investigation of the whole subject.

5. Researches regarding the Mode of Infection.—These really began with the old attempts mentioned in section 3 to find the infective organism in marsh water, and with those mentioned in section 4, and culminating in the negative efforts of Zeri (1890) to infect healthy persons with such water. Parallel researches on various worms and on *Piroplasma bigeminum* were referred to in the last section. I have now to describe my own work. Entering the Indian Medical Service in 1881 I was much struck by the misery caused among the people by this and other diseases; and in 1889, during leave in England, studied bacteriology and public health, with a view to undertaking pathological investigations. On returning to India I was especially drawn to the difficult problem of
Paludism, regarding which the facts observed by me did not accord well with the old hypothesis of a marsh miasma. I was first led to the ideas of Broussais that the disease might be due to intoxication from intestinal organisms. In those days it was almost impossible to obtain much literature in India; and Laveran's discovery was obscured by writers who, in attempting to find his parasites in the blood, found only natural objects which resembled them. I detected the error and, with many others, doubted his discovery in consequence, and failed to find his organism—though I obtained much valuable practice in microscopic work. In 1894 I returned to England, where Manson showed me the true Laveran's bodies. He also read me his new mosquito hypothesis; and I reminded him that the same idea had been mooted by Laveran. Next year I returned again to India, determined to work out the whole subject thoroughly. The details have been previously recorded in my Nobel Lecture [1905], but the reader should know the following points.

Little was then recorded regarding the structure, habits, or classification of mosquitoes, and I could obtain no literature on the subject, and was obliged to find out everything, including the technique, for myself. I was not then aware of the speculations of Beauperthuy, Finlay and King, or the discovery of Smith and Kilborne.

There was nothing to guide me as to the species of mosquito concerned, as we had no right to assume that the malaria-bearing species is necessarily the commonest in any malarious locality; and as metaxeny was not known at that time among intercellular parasites of animals, there was nothing to indicate its form or position that Laveran's bodies would, by supposition, be in the insects. The study of these minute organisms was moreover much more difficult than that of the large worms already investigated; and the proper method of staining was not then known.

In May 1895 I fed Culex and Stegomyia bred from the larvae.
on patients with the gametids (crescents) in their blood, and showed that the motile filaments were, as usual, extruded in the insects' stomachs. But I speedily found that, owing to their minute and delicate structure, it was impossible to follow them further, as Manson had suggested should be done. I was therefore obliged to adopt a new procedure of my own. The insects were kept alive after being fed for several days, and were then exhaustively searched for any parasites they might contain. If such parasites were found it was possible that they might be the developed motile filaments; and the point could be cleared up by subsequent experiments. This method was extremely labourious, but was the only one possible. For more than two years the results were completely negative.

Meantime, following the later conjectures of Manson, I tried to infect healthy persons by giving them to drink water in which fed mosquitoes had died. By some accident the first case appeared successful; but twenty-one succeeding experiments practically failed [1896].

For this and other reasons I abandoned this part of Manson's hypothesis, and began to think that the insects probably carry the parasites from man to man, either depositing them by defaecation on the skin of healthy persons, or inoculating them under the skin after puncture. In August 1896, Mr. Appia, Assistant Surgeon of the Civil Hospital at Bragalore, kindly submitted to the suggested experiments. Many Stegomyia and Culex, previously fed on patients, were fed on him a few days later. There was no result—the mosquitoes being of the wrong species, and the period between the feedings being too short [1896].

Bignami now criticised Manson's hypothesis [1896]; but I made a number of experiments in support of it, and showed that the extrusion of the motile filaments is really a living process and not a "death agony" as many had thought [1897].

My repeated failures, however, now persuaded me that I had probably been working with the wrong kind of mosquitoes.
RESEARCHES ON INFECTION

Colour and Stagnation: and in April 1897 I went to an intensely malarious spot near Ootacamund in the Nilgiri mountains, in order to see if I could find another likely kind. Then, for the first time, I saw an Anopheline—the really culpable kind; and also made several observations which made me finally abandon the second part of Manson's hypothesis and adopt the view that the insects carry the parasites in some way from man to man [1897].

A few months later I returned to Secunderabad, where I had commenced my mosquito work in 1895, and was at last rewarded with success. On the 20th and 21st August I found the zygotes of the parasites in two large dapple-winged mosquitoes which had been bred from the larvae, and fed on a case containing crescents. This fortunate observation gave the clue to all that followed, because it indicated the form and position of the parasite in the insect and also the variety of insect capable of carrying it. The problem was practically solved, and only details and formal proofs required to be substantiated.
The matter was reported at once to Government, and the medical press [1897]. Unfortunately no more of the large dapple-winged mosquitoes could be obtained, but I found the pigmented cells in a Culex which had been caught feeding on a case of tertian malaria, and also in one of a smaller kind of dapple-winged mosquito. On this, I wrote to Manson telling him to expect the full solution of the problem in a few weeks. Next day, however, I was ordered to proceed to Kherwara, a place a thousand miles distant, where there was little malaria at the time. Owing to this interruption I have never been able to identify exactly the two species of dapple-winged mosquitoes; but from their general characters, the markings on their wings and the shape of their eggs, they were obviously anophelines.

I remained at Kherwara from September 1897 to February 1898, when the Government was good enough to put me on special duty to continue my researches in Calcutta. On arrival there, I found it impossible to work with human malaria, chiefly on account of the riots caused by Mr. Haffkine's anti-plague inoculation, and therefore attacked the malaria of birds. According to Manson's hypothesis, the motile filaments were flagellated spores capable of living in mosquitoes' tissues; but my pigmented cells contained plasmodia, which cannot exist in spores. The discrepancy was explained by a series of researches made in 1896. Metchnikoff and Simond had found similar motile filaments in Coccidium ovis, of rabbits, and suggested that they are really sperms and not spores [1897]; and a little later MacCallum and Ope in America actually observed, in the case of one of the malaria parasites of birds (Halteridium) and one of those of men, these sperms in the act of fertilising the female cell [1897]. My pigmented cells were therefore the fertilised cells, or zygotes, still carrying the plasmodia which they originally possessed.

In March 1898, I found these bodies again in Culex fatigans.
RESEARCHES ON INFECTION

fed on birds containing Plasmodium (Proteosoma) danilewskyi.

In a few months, by means of rigid experiments, the development of the parasites in the insects was fully ascertained. On the 4th July I observed the extraordinary fact that the sporozoites (sporozoites) of the parasites enter the insects' salivary or poison glands, thus suggesting that infection is produced by the bites of the insects. I had thought that this might be the case, but none of us had ever imagined such a wonderful process—nature surpassed the divination of all of us! In July and August I infected twenty-two out of twenty-eight healthy sparrows and some other birds, by means of the bites of Culex jatigans which had been previously fed on infected birds.

These experiments gave the fundamental solution of the problem, and the first proof of metaxeny among unicellular parasites of animals—just as Ktichenmeister's had proved the process to hold for higher organisms. They exhibited, with the assistance of MacCallum and Opie's observation, the whole development, step by step—the position and form of the parasites in mosquitoes, and the wonderful method of infection. Owing to the great similarity of the avian and human parasites, there was no doubt that the latter had the same history—and indeed the stages of these up to the fifth day had already been found by me a year previously in Anophelines.

I was now anxious to complete the work on human malaria, but was ordered to leave the subject and attack the difficult one of malaria. This, with the writing of the necessary report, occupied me for nearly six months, until I left India in February 1899. I then joined the newly-formed Liverpool School of Tropical Medicine; and at the end of July set out with E. E. Austen, Entomologist at the British Museum, and Dr H. E. Annett, of our School, to complete my study of the human parasites. In a few weeks I was able to show that the parasites of quartan, tertian, and malignant fever all develop in Pyretophorus costalis or Myzomyia junesta, precisely as the Proteosoma of birds develops in Culex jatigans. This
completed the task; and I now turned to the subject of practical prevention.

6. Confirmations and Extensions.—My observations of the parasites in mosquitoes were published by myself in a series of papers on 26th December 1897, 26th February 1898, 21st May 1898, 11th October 1898, and 24th January 1899, and also owing to official delay in regard to some of my reports by Manson on 21st June 1898, July, and 24th September 1898. My paper [May 1898] contained a full account with plates of the necessary technique invented by myself and of the stages of *Plasmodium* in the mosquito up to the sporulation of the zygotes—the mode of infection being published in the later papers by Manson (to whom I had telegraphed the news in time for the Annual Meeting of the British Medical Association at the end of July), and also by myself [October 1898]. Moreover, I had sent numbers of my specimens to him and to Laveran; and, in fact, by August 1898 my researches were well known to most workers at the subject in Europe and America.

The first to confirm them was R. Koch, with Kossel, who in September followed completely the development of *Plasmodium* in *Culex minax*, and demonstrated a point which I had not had time to deal with, namely, how the zygotes traverse the wall of the insect’s stomach [1899].

In December, C. Daniels, sent by the Royal Society to examine my results, arrived in Calcutta and confirmed them [1899]. He and Dr Rivenberg also assisted me greatly at that time.

Until my researches were published, the Italian writers had generally disbelieved in the mosquito hypothesis, though A. Bignami had accepted it on the lines of Lancisi and King. Now, however, they made strenuous efforts to follow; but they reached no tangible result until November, when Bignami, in the light of my experiments on birds, infected a man in Rome with mosquitoes brought from Maccarese [November 1898]. A
few weeks later A. Bignami, G. Bastianelli and R. Grassi followed the zygotes of malignant malaria in Anopheles maculipennis, fifteen months after my original success with the same parasite in Secunderabad, and four months after the whole life-cycle of the parasites, as exemplified in Protoplasma, had been fully published by Manson and myself. They were thus able to (overcall the completion of my work) on the human parasites, but did so entirely by following my previous researches, while my time was being wasted over a lengthy report on kala-azar—a duty which I was not permitted to postpone. Being very favourably placed for the work, and not being subject to interruptions, they succeeded in infecting three more persons, and were able to publish numerous papers with coloured pictures, which greatly popularised the subject. They proved one important new fact, however—that the tertian parasites also are carried by the Anopheles; and I verified this later in Sierra Leone. In my original successes of 1897 with the human malignant parasites, and described my work to the printed notice of my words [December 1897], that the mosquitoes used by me had not been bred from the larvae—which was in reality a very difficult task, requiring the same reservations for other members of the group. The life-history of Protoplasma, J. Bignami and myself described the same, since then, persons, with three of the human parasites, and inserted Klein the same as these, since then, and the work of my colleagues is the same as that of my own. The life-history of Protoplasma is therefore the priority in the case of all similar life-histories; and is in fact identical with those, since found, of other unicellular organisms. Efforts were also made, with the same object, to discredit my original successes of 1897, and to persuade the world that I had discovered the "Anopheles malariarum" independently of me [1900, p. 31]. Unfortunately for him he had referred to my work in a paper (October 1898), which he had published two months before he "discovered" anything at all. There is no doubt that he and his colleagues recognised the genus of our "dusky-wing" mosquitoes from several statements of mine, and were given easy access to the parasites in numbers of the same group in Italy. The Italian work was done by Bignami and Bastianelli, and in this letter to my colleagues I mentioned here certain misstatements are apt to discourage genuine work in Italy, 1905."

1 The relations between the work of these authors and of myself are exactly discussed in my lecture [1903]. For a long time many were convinced in their mind of the priority of the mosquito-cycle of the important human parasites, and to me only the study of the human Protoplasma of India. But according to physiological rules, priority in the discovery of the life-history of any group of organisms belongs to the investigation which first discloses the new life-history in any member of the group—which is in reality done, since it is usually the difficulty in repeating the same reservations for other members of the group. The life-history of Protoplasma therefore belongs to the priority in the case of all similar life-histories; and is in fact identical with those, since found, of other unicellular organisms. Efforts were also made, with the same object, to discredit my original successes of 1897 with the human malignant parasites, and described my work to the printed notice of my words [December 1897], that the mosquitoes used by me had not been bred from the larvae—which was in reality a very difficult task, requiring the same reservations for other members of the group. The life-history of Protoplasma is therefore the priority in the case of all similar life-histories; and is in fact identical with those, since found, of other unicellular organisms. Efforts were also made, with the same object, to discredit my original successes of 1897, and to persuade the world that I had discovered the "Anopheles malariarum" independently of me [1900, p. 31]. Unfortunately for him he had referred to my work in a paper (October 1898), which he had published two months before he "discovered" anything at all. There is no doubt that he and his colleagues recognised the genus of our "dusky-wing" mosquitoes from several statements of mine, and were given easy access to the parasites in numbers of the same group in Italy. The Italian work was done by Bignami and Bastianelli, and in this letter to my colleagues I mentioned here certain misstatements are apt to discourage genuine work in Italy, 1905.
In November 1899, R. Koch, who has given such great discoveries to pathology, added another in connection with malaria. He found in the valley of Ambawara in Java that while large numbers of the native children showed the parasites in their blood, the adults seemed to be comparatively free from them, and had obviously become partially immune. Thus in most very malarious places it is chiefly the children who suffer from the acute disease. The blood of those who survive gradually produces something which after a number of years has the power of reducing and perhaps extinguishing the parasite invasion. From this it follows that in such localities the Anophelines must become infected principally from the native children (see section 31 (g)).

In the summer of 1900, P. Manson carried out an important crucial experiment. A number of Anophelines maculirostris, fed on cases of mild tertian, were brought from Italy to London, and were allowed to bite P. T. Manson there on several occasions. He developed the disease on the 13th September, the tertian parasites being found in his blood a little later. The insects were also allowed to bite G. Warren, who was similarly attacked fourteen days afterwards. At the same time L. Samboh, G. C. Low and two others lived for three of the most malarious months in one of the deadliest places in the Roman Campagna, Ostia, without contracting the disease, because they spent the nights in a hut protected by wire gauze against the entry of mosquitoes.

On many other occasions healthy persons have been similarly infected on the lines of my experiments with birds in July to August 1898. As already mentioned Bignami and Bastianelli infected four persons in Rome (which is itself free from malaria) in 1898-1899. Subsequently C. F. Fearnside at Rajamundri in India infected seven out of eight persons, including himself, in 1900-1901 [1901]. W. Schiifner infected himself and two others at Delhi, Sumatra, in August and September 1902, two with tertian and one with malignant
malaria, by means of certain Anophelines [1903]. N. Jaccó infected ten out of fifteen persons at Kolozsvár in Hungary in 1904 by means of A. maculipennis (section 17).

My work on the Proteosomia of birds has been confirmed by Koch [1899], C. Daniels [1899], B. Grassi [1900], R. Ruge [1901], R. O. Neumann [1901].

The mosquito cycle of the human parasites has been further worked upon by Fernsle [1901], Stephens and Christophers [1899-1903], Schöfler [1902], Jancó [1902], Schaudinn and others.

Reviewing this history we shall see that the great stream of research on malaria, descending to us through more than two thousand years, is composed of three main tributaries finally mingled together. One tributary rises in the work of the ancients on the different clinical forms, and consists of the discovery of the cinchona bark; the work of Trott (1735); the discovery of the plasmodin by Meckel (1847); of the parasites by Laveran (1880); and of the confirmations and extensions of Golgi, Danilewsky and many others.

Another tributary consists of the ancient observations connecting the disease with marshes; the speculations of Varro, Columella, Lassé, Baasberger, King, Laveran, Koch and Manson; and the valuable researches of those who tried to find the organism in marshes.

The third tributary consists of the early work on parasites: the discovery of metacyclic by Abildgaard (1790), Steenstrup (1842), and Kuchenmeister (1851); the discoveries of Leuckart, Fedtschenko (1856), Moloskov (1860), Manson (1877), regarding certain worms; that of Smith and Kilborne (1896) regarding Piroplasma; of Bruce on trypanosomes; my work on human and avian malaria (1895-1899); and the confirmations and extensions which followed.

7. Recent History of Prevention.—It is open to question whether the extensive drainage works of the ancients had
been carried out for sanitary or for agricultural purposes; but there is no doubt that for several centuries the Italians, and other nations, have known how to control malaria by drainage and allied measures. In fact, for a long time the statement that drainage reduces malaria has been generally accepted as a medical dogma. As soon as the mosquito theorem began to become consolidated, the question arose whether the new knowledge would not provide us with some easier and cheaper method of prevention. My own studies had been undertaken principally for this object; and the following observations of mine were connected with it.

As early as 1884-1885 in Bangalore, and many times since then, I had noticed that *Anopheles* and *Culex* could be largely reduced in numbers in my own house by emptying out the stale rain-water collected in tubs and pots in the garden. On one occasion I offered to reduce these mosquitoes in the regimental mess-house, but the adjutant objected because, he said, I should be disturbing the order of nature! But I satisfied myself as to the possibility of making such a reduction by my own personal experience in many parts of India.

After incriminating my dapple-winged mosquitoes (*Anopheles*) in Secunderabad in 1897 I studied their habits there and in Kherwara, Calcutta, the Darjeeling Himalaya region, and Assam, and noted the following points.

The eggs of the *Anopheles* were more or less boat-shaped, and possessed a peculiar membrane which gave them the appearance of having a row of oars on either side—thus differing from the eggs of the *Culex* and *Stegomyia*. They were also apt to arrange themselves in triangular patterns on the surface of the water. The larvae floated flat on the surface and had no long breathing tube—being thus unlike those of the other common groups. The adults were generally differentiated by having spotted (dappled) wings; a shape more suited for...
long flight; and a peculiar attitude, when resting, at an angle to the surface to which they cling. These points would enable any one, even uneducated labourers, to distinguish them. But above all, my native assistants and myself noticed everywhere that the larvae do not generally breed in the pots and tubs occupied by those of the other groups, but mostly in pools of water on the ground. This led me at once to the explanation of the central fact that malaria is connected with marshes. If Chik and Stigomyia had been responsible for the disease it would not have possessed this relation—it would have been connected with pots and tubs, etc., just as yellow fever, which is carried by Stigomyia, is connected with them. I did not then know that the quartan and tertian parasites are also carried by Anophelines, but guessed, from the well-known relation referred to, that they were carried by some kind of marsh-breeding gnat, and not by the pot-breeding ones. The explanation was now clear; the ancients were quite right—the disease is caused by an emanation from the marsh. That emanation, however, is not a gas, nor even a contagium vivum, but an insect.

It was observed also that the Anophelines do not breed so much in large open bodies of water, such as lakes, rivers and reservoirs, but more in small, shallow, and often grassy pools and puddles where they can obtain shelter from wind and fish; and that like other mosquitoes, they abound most in proximity to their breeding-places. Putting all these facts together, I reasoned that we now possessed a much cheaper and easier method of prevention. Previously, we had been obliged to drain a whole area at great cost; now we should be able actually to seek out and determine the exact malaria-producing pools, namely, those which contain the larvae, and then to fill up or drain those alone; and I naturally inferred that if the old method had been feasible (as it had been in many places), the new method would be still more easily feasible, and at less expense.

Before leaving India I described my proposals in a short report...
to Government, dated the 16th February 1899, and published five months later without date, and with a title given apparently by the editor [1899]. The matter is so important, and my views have been so much misreported, that I must reiterate exactly what I said. I pointed out that mosquitoes in general "are seldom to be found in the larger bodies of water"; that to get rid of them locally "it will suffice to empty out or drain away or treat with certain chemicals the small collections of water" in which they breed; that the Anophelines "seem to choose only rain-water puddles and ponds too large to dry up under a week or more, and too small or too foul and stagnant for minnows." I said that such pools "are not common in most parts of India except during the rains," and "seem to be so isolated and small that I think it may be possible to exterminate this species under certain circumstances." I added, however, that "I wish to be understood as writing with all due caution on these points." "I limit this statement to certain localities only, because it is obvious that where the breeding-pools are very numerous, as in water-logged country, or where the inhabitants are not sufficiently advanced to take the necessary precautions, we can scarcely expect the recent observations to be of much use—at least for some years to come. And this limitation must, I fear, exclude most of the rural areas in India. Where, however, the breeding-pools are not very numerous, and where there is anything approaching a competent sanitary establishment, we may, I think, hope to reap the benefit. . . . And this should apply to the most crowded areas, such as those of cities, towns and cantonments, and also to tea, coffee and indigo estates, and perhaps to military canton." "In making these suggestions I do not wish to excite hopes which may ultimately prove to have been unfounded." I concluded by urging further investigations on the malaria-bearing mosquitoes of India and their habits. Though the report, being hurriedly written, might have been more exactly expressed in places, it is correct enough.
As it was the original statement of the radical anti-malaria measure—which has since been used with success in many parts of the world, and will certainly be adopted in the future as a fundamental principle of tropical urban sanitation—the reader should now clearly grasp what exactly was proposed. Animals tend to abound most where the local conditions are most favourable to them. Conversely, if we can make the local conditions unfavourable, they should become less numerous. Also, malaria being carried by certain Anophelines, should, as a broad general principle, be most common where they are most common, and should be reduced where they are reduced. I proposed, therefore, to reduce their numbers by measures directed against their breeding-places. But this proposal was obviously not meant to apply to the whole world, but only to places where the measures were most likely to be feasible—that is, generally to “crowded areas” and not to “rural areas.” A square mile of town, containing thousands of ratepayers, may be assumed to have money available for such work, while open country, containing perhaps only a few scattered houses, has no such funds. Moreover, mosquito-reduction in a town will benefit thousands of people, while in the country it will benefit only a few—and that for the same cost. An identical principle applies to pipe water-supply and to pipe-sewerage systems—these are frequently given to towns, but not so often, even in Europe, to widely-scattered farmhouses. If then, I argued in effect, a town can afford to provide its inhabitants with a piped water-supply, or a sewerage system, it ought also to be able to keep them free, partially at least, from such dangerous insects as mosquitoes. At that time I had had a rather exceptional experience of practical sanitation, having been specially appointed by the Government of India to improve the sanitation of a large Indian town (Bangalore), and I knew what I was writing about. As a general rule it would be much cheaper, I thought—and probably every practical engineer or health officer will agree with me—to make a great reduction
of mosquitoes in most towns, than to install and maintain a piped water-supply or sewerage system. I held also—and still hold—that the same measures might be feasible in some cases, even in plantations, military camps and villages.

Unfortunately there are many people who seem to regard any new idea as a personal affront—who never try to understand the author, who disregard his reservations, and who attribute to him any absurd opinion! I was immediately accused of proposing to destroy every mosquito throughout India and Africa, and of trying to upset the order of nature, and so on. Still worse, many others accepted this idea without understanding the practical details, and did much harm by attempting the work in quite unsuitable places. Lastly, some rejected the idea, but pretended to test it experimentally—and of course failed.

In 1899, owing to the efforts of a number of medical men and men of affairs, and largely to the recent work on malaria, schools of tropical medicine were opened in Liverpool and London. At my inaugural lecture at the former (published at the same time as the previous paper) I repeated the same suggestions [1899]. Judging from my Indian experiences, I overstated somewhat the difficulty of reducing Culicines; but concluded by invoking experiments on such points.

West Africa, a great country hitherto paralysed by malaria, had long attracted me as an objective for practical preventive work, and I dreamed that it might be revolutionised by it. Hence, no sooner was the Liverpool School of Tropical Medicine opened, then I proposed to the Committee that I should be sent there to study the subject in detail. Consequently I left England in July (1899) with Dr H. E. Annett of the School, and Mr E. E. Austen of the entomological department of the British Museum, to see what could be done in Freetown, the capital of Sierra Leone—long known as the

1 Malcolm Watson (section 57) is now extending Anopheline reduction to rural areas as well as towns. See also sections 41 and 42.
"white man's grave." As already stated (section 5) we quickly incriminated two local Anophelines, *P. falcatus* and *Anopheles funestus*, as carriers of malaria; and then set out to study their habits with a view to elaborating the principle of mosquito-reduction for practical sanitation.

Before we left it was arranged that our work should be published anonymously in the medical press as promptly as possible for the guidance of others; and I consequently wrote a series of six articles which were published in the British Medical Journal in September and October [1899]. The first two of these described the finding of the carriers; but the two latter (30th September, p. 869, and 14th October, p. 1033) gave the leading points in the habits of the Anophelines, the broad distinctions between them and the Culicines, the nature and distribution of their breeding pools, and other matters connected with the general theory of malaria, together with a plate showing the characteristic attitude, and one showing a characteristic breeding-pool. In all these points these Anophelines of Sierra Leone proved to be generally similar to those which I had studied in India. The articles drew wide attention to the subject; and in fact formed the basis of our work on the reduction of mosquitoes for malaria done since then; though, being anonymous, they are not often referred to in the literature of the subject.

Being obliged to hurry back, we could spend only seven weeks in the Colony; and, as we were only private individuals, we could not carry out our recommendations. In February 1900 we published our report; in the main body of which I summed up my results and recommendations with plates and figures. Operations for reducing the Anophelines were divided into those meant to prevent their breeding, such as draining...
or filling the pools or treating them with Culicides (oil, tar, lime, etc.); and the destruction of the adults or larvae. I devoted a whole section to discussing the local conditions under which such operations were likely to be successful, and concluded as follows:

"(1) Operations against *Anopheles* are least likely to be effectual in level, water-logged localities, and in places where the insects breed in pools which cannot easily be found or cannot easily be treated. (2) Operations will probably be easier in country which is not quite level, or where the rainfall is not great. (3) They promise to be very easy in extremely dry places. Lastly, it goes without saying that we cannot ever attempt to deal with *Anopheles* in large rural areas. On the other hand, we may reasonably hope to reduce them, if not to exterminate them, in the principal centres of population and civilization—that is, in the places where the prevention of malaria would be most useful—provided always that we make intelligent and persistent efforts to do so." Also, both in this report and in a previous small book of instructions for laymen (1899), I discussed personal prophylaxis by the use of mosquito nets, etc., and the reduction of Culicines round houses; and I also pointed out how much Europeans in Africa suffered from not being segregated from the natives as they are in India (February 1900, p. 435).

I have described these thoughts and studies at some length, because they constitute the conclusion of my work commenced five years previously, long before others had considered the matter worth touching, and therefore have, I think, the right of priority. But, as I have already stated, immediately after the publications of my work in the middle of 1898, numbers of medical men and naturalists began to take up the matter in many parts of the world. The classification and habits of the

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1 I had also in the same year that a single intelligent weapon agent might be a great boon. A quote in *Nature* by the writer of *Culicines* by many men. On the strength of this I have very much been accused of proposing to kill the whole of Fennecos by one man only.
Anophelines and other mosquitoes specially interested them, and innumerable papers and works on the subject began to be poured out. The entomological results were invaluable. Whereas in 1898 only about a hundred species of Culicidae were known, we have now recognised about six hundred, which have been carefully described in valuable works by E. E. Austen, G. F. Giles, L. O. Howard, R. Blanchard, and especially in an exhaustive monograph, by F. V. T insult, and by many others.

Regarding the habits of the insects my findings have been generally confirmed, without very much really new matter being added. Some of the observers, being new to the subject, have laboriously recorded facts (such as the abundance of gnats near their breeding-places, or in ground-holes of houses, or in dark corners, or on dark surfaces, or their transportation by carriages, and so on), which I think, were perfectly familiar to all who have lived much amongst them.

Returning to the subject of prevention, we must now note that an important new method was suggested by R. Koch during his visit to Italy in 1898—namely, prevention by treatment of cases. This was tried at once by B. Gosio in Grosseto in Italy [1900]. Towards the autumn of 1899 Koch went with R. Pfeiffer and H. Kossel to Batavia, where he discovered his law regarding the frequency of infection in native children; and in December proceeded to German New Guinea, where he successfully used his method of prevention at Stephanort [1900]. This method is entirely different to the ancient one of drainage, or to my modification of it. It aims, not at the reduction of the carriers of the parasites in a locality, but at the reduction of the parasites themselves by the general and complete treatment by

1 Also many habits have been ascribed to mosquitoes, which exist only in the imagination of the writers. Thus Reclus says that Aaron suggested destroying mosquitoes by placing small lamps in yards of houses over pools or ashes near dwellings. The gnats, attracted by the light, would fall into the oil. In 1899, two Italian writers, one of whom is supposed to have led the way regarding the mosquito method, wrote: "Not only appeared this entirely, but within the responsive that the lamps "he furnished with powerful (oil) reflector turned away from the house." I have never in my life seen mosquitoes attracted by lamps.
the principal enemy of the colony, little had been done. The Acting Governor, now Sir Matthew Nathan, who had been very sympathetic during our visit in 1899, had left for the Gold Coast; and, beyond appointing a single person for a few months to check the mosquito, the municipality of Freetown had dropped the matter. Calcutta, where also I had suggested an anti-mosquito campaign in 1899, had done the same. Everywhere, my proposal to reduce mosquitos in towns was treated only with ridicule.

Early in 1901, therefore, I determined to try and give an object lesson in the work recommended by me. A rich gentleman of Glasgow kindly offered me £2,000 to defray expenses; and others helped me in various ways. On the 2nd July I arrived with Dr M. Logan Taylor, at Freetown, and, with the support and approval of the Governor, Sir Charles King Harman, commenced the work at once. Since 1899 I had gradually become convinced that anti-mosquito campaigns had better be conducted, not only against Anophelines, but against all kinds of mosquitos at once; and this opinion was strongly reinforced by the yellow fever discovery just made, and also by the fact that certain Culicines carry filaria. In fact, since then I have always maintained the opinion which may be expressed as follows: It is one of the first sanitary duties of all municipalities and town councils in warm climates to keep down as much as possible the numbers of mosquitos within the area placed under them. We therefore engaged the services of twenty men, to whom the Governor added twelve; and with these we removed piles of mosquito-breeding rubbish from the back yards of houses, and drained, emptied, filled up or oiled numbers of Anopheline pools. I returned to my duties in Liverpool on the 16th August; but M. Logan Taylor continued the work. In September C. W. Daniels of the London School of Tropical Medicine arrived in Sierra Leone, and reported favourably on the work; and in January 1902 I visited it again for a week to watch progress.
There is no doubt that a great reduction in the number of mosquitoes was effected by our measures; but, of course, our work was meant only for a temporary object lesson, and we stated clearly that the improvement would last only if our measures were continued by the local authorities. Later in 1901, however, Logan Taylor reported that these authorities did not appear very anxious to continue them; and we consequently closed the work when our money was expended. Having done, we thought, as much as private persons could do.1

After my third visit to Freetown, Prince August d'Arenberg, President of the Suez Canal Company, asked me to advise regarding the prevention of malaria at Ismailia on the Canal. I arrived there in September 1902 with Sir W. Macgregor, who did me the honour to accompany me. The town was swarming with both Culicines and Anophelines; and efforts to control the malaria by liberal quinine distribution had not succeeded. I advised a continuance of this measure with general mosquito-reduction. In this case "intelligent and persistent efforts" were made; and within a year the insects of both groups were almost entirely banished, and the admissions for malaria reduced from about 2,000 a year to 214. Since then, endemic malaria has entirely disappeared. Dr A. Pressat says that he originally reduced the disease by means of a mosquito brigade of only four men qui a tout fait [1904]. Scarcely less brilliant was the campaign at Klang and Fort Swettenham in the Federated Malay States, commenced in 1901, and carried out chiefly by Dr Malcolm Watson. At Hong Kong also, a campaign was commenced at the same time, and carried out chiefly by Dr J. C. Thomson with very good results. Several anti-mosquito campaigns have been conducted in the United States; and in 1906–1907 my brother, E. H. Ross, acting under the orders of Sir Horace Pinching, 2

1 A year later it was pretended that our efforts had failed, and the only thanks which we ever received for our pains was a subterranean effort to injure us.
completely cleared Port Said of Culicines. Other campaigns have been those of Dr A. Halsey at Khartoum, of many officers in Candia, some West Indian Islands, the East Indies, and Durban. In 1906 I went to Greece to advise regarding malaria at Lake Kopus; and in 1907 to Mauritius (with Major C. E. F. Fowler) to advise the Government on malaria prevention there. As regards magnitude, however, the great American campaign, under Colonel Gorgas, against both malaria and yellow fever, at Panama; that of Oswaldo Cruz at Rio Janeiro; and that, so well guided by Drs Ed. and Et. Sergent in Algeria, have long held public attention. Descriptions will be found under the appropriate sections in this book.

In spite of these brilliant examples, however, little was attempted against malaria for many years in the vast bulk of tropical countries. It is true that questions in Parliament and elsewhere often led to assertions that much was being done; but those who really know what might have been done and who were in a position to obtain the information from men on the spot, remained far from satisfied. On 23rd April 1906 the Earl of Elgin, Secretary of State for the British Colonies issued a circular at the instance of Colonel Seely, M.P., to all Governors of Crown Colonies asking for specific details on this point. In September of the same year I read a paper at the 14th International Congress of Hygiene at Berlin (1907) in which I described what had been done in some tropical localities and also criticised the lack of efforts in others. Still, however, little effect was produced, and I came to the conclusion that in many malarious places the authorities had no real desire to carry out anti-malaria measures, or else were entirely ignorant of how to do so. For example, though they always urged lack of funds as an excuse, they often omitted to do things which would cost almost nothing, such as to undertake the measurement of malaria, to issue careful reports, or to form the nucleus of an organisation.

At the end of February I visited the Medical Congress at
Bombay in order to ascertain what work was being done in India, but met only with disappointment. A few months later, therefore, I gave a lecture at the Royal Institution of Great Britain, in which I ventured to complain very strongly regarding this state of affairs [1909]. Fortunately this has been followed by a considerable improvement. An anti-malaria league was started in South Africa, and the Indian Government held a conference on malaria at Simla, which practically endorsed all our teaching. Moreover, other movements for the generalisation of anti-malaria measures are now on foot, and will, I hope, produce better results.

8. Remarks.—Such in brief is the august history of malaria—and some day it will be considered as being an unimportant part of the world’s history. To the thoughtful student of human affairs it contains many points of interest. We should note in the first place that several methods of prevention were well known long before the mosquito-theorem was established. Probably the ancients, and certainly the Italians, since the time of Lancisi (1717), were so well acquainted with the good effect of drainage that this principle was accepted as a dogma in all the medical schools. The excellent results of quinine, both for cure and prevention, have also been well known, at least since the time of Maillet in Algeria (1830)—so well known in fact that the Government of India has sold the drug for many years at the public post-offices for a small price. Even the benefit of using a mosquito-net during sleep was, I remember, looked upon as an elementary doctrine when I first went to India in 1881. The mosquito-theorem has merely verified and precised these old ideas.

It was therefore I think possible, long before 1899, to reduce the disease anywhere on a large scale. Efforts in this direction would have been invaluable in numbers of settlements in Africa and in the East and West Indies; but were, I believe, seldom if ever made. Certainly many intelligent medical men...
advocated them; but there is a wide interval between the suggestion of public health measures and their execution. Where they were commenced they were soon abandoned; no continuous public policy against the disease seems ever to have been adopted; settlements were left for years at the mercy of marshes known to be poisonous; and the methodical distribution of quinine remained undreamed of. I have little doubt that if more intelligence had been shown in these respects many of these settlements would have already grown into prosperous states.

Laveran's discovery of 1880 was one not only of the theoretical, but of practical, importance. It enabled medical men to distinguish with certainty cases of malarial fever from other diseases, and, after making the diagnosis, to treat the patient methodically.

But many years elapsed before it began to be used for these purposes. The parasites were not seen in India, for example, until 1882 (by Vandyke Carter). I did not hear of the discovery until 1888, and did not see the parasites until 1894. Scarcely half a dozen men were studying them in India at that time. The use of the microscope scarcely became general anywhere in the tropics until after 1900; and quite recently medical men have told me of hospitals which were not even provided with these indispensable instruments. Numbers of others had never read the fundamental literature; and up to the present day many colonies possess no sufficient organisation for circulating recent medical papers. Yet in most tropical countries there were large public medical services which ought to have been properly provided for in these respects.

It is surprising, when we remember that malaria often causes a third of the sickness in a place, to note that Laveran's discovery was not immediately followed by public investigations on the subject, especially as to the route of infection. The work was done almost entirely by private persons. Even when

1 In 1898 the Government of India appointed me to undertake researches on malarial—this being, I believe, the first case of the kind.
Information was thus obtained, it was left for years untangled in the medical schools, or neglected in practice. But worse than this little has been done even to encourage the private workers. Indeed I know of several cases where such workers have received for their pains nothing but the ridicule of less laborious colleagues, and the persecution of jealous superiors.

There was no reason why the prevention of malaria according to the new methods should not have been commenced after 1899 in every civilized malarious country. Such countries possess responsible governments and expensive sanitary and medical services—in fact, all the machinery required for the work. But the efforts actually made have been due almost entirely to isolated enthusiasts, while in many places nothing approaching a genuine campaign has even yet been attempted. In others, again, some efforts have been reported, but their perfunctory nature is only too apparent to those who are acquainted with the subject. Yet the work has been done, and well done, in many places. Why then has it not been done in all?

The facts are undeniable. In numerous localities the disease causes not only an immense amount of sickness, but a great loss of efficiency amongst officials, soldiers, workmen and the general public, and a corresponding waste of public money and reduction of prosperity. It can be combated only by well-organized government action; and governments admit their responsibility in such matters. Yet governments have taken little part in the investigation of malaria, and have even neglected to utilise for practical purposes the investigations of others. Nor is the case of malaria the only one of the kind. Filariasis is very prevalent in many localities, where it produces numerous unpleasant diseases; yet Sir Ronald Ross's discovery of 1877, that the parasite is carried by mosquitoes, has scarcely ever been utilized up to the present except perhaps in the case of certain parasites transmitted through the bite of the sand fly by Sir Ronald Ross himself.

1 The treatment of my brothers in Egypt is well known. In British administration we do not expect gratitude for valuable work; but to feign anything more obdurate than to punish such labour by gratuitous persecution!
Another example (and I could quote many) is that of the entry of plague into India in 1896—an event which has destroyed millions of lives and wasted millions of money. Precisely similar complaints are frequently heard regarding diseases of animals and of crops, and regarding mining, manufactures and commerce.

The student will do well to ask himself the cause of this phenomenon—which is of fundamental importance in connection with our subject. We recognise, of course, that the world is by no means perfect; but for this very reason we should endeavour to extricate the causes of its imperfections. The following points may be suggested for consideration, or correction, by the reader.

The principal cause of the faults referred to seems to me to lie in a curious tone of thought which is now very prevalent, especially in this country; according to which all matters of practical utility to mankind are looked upon as being rather base preoccupations for the more perfect type of human being. The study of nature, the extirpation of disease, the management of cities, invention, the development of agriculture, manufactures and commerce, and the organisation of prosperity are inferior things. We are to seek a higher level in personal manners, literary criticism, eloquence, sport, party politics, sectarian dogma, and so on. It is the modern equivalent of Indian fakirism, by which, lost in various lofty speculations, we are taught to remain content in the midst of starvation and disease.

This spirit, fostered in us from childhood, leads to false ideas of government. The scientific side of administration is apt to be forgotten in the noise of endless and despicable party strife; progress ceases while we discuss abstract notions about law, liberty, representation, nationalism and so forth; the machine refuses to work while the mechanics are quarrelling over the lubrication. The result is precisely what may be imagined—cities built without sense or forethought, filthy slums, bowels filled with disease, guls of destitution; and the voices of
those who would better this state of affairs by scientific methods are lost among the yells of the opposing factions.

Though in the tropics we are still spared many of the evils of party government, the same spirit of utilitarianism often remains. Money which would suffice for the amelioration of whole towns is wasted rather on the construction of extravagant town halls and post-offices. The cost of a new hospital would suffice to prevent more cases of sickness than are treated in it; and that of invaliding to prevent the disease which causes it. The British Government spends £5,000,000 a year on the education of children; but gives, I believe, literally nothing for the scientific investigation of scarlet fever, measles, whooping-cough, chicken-pox and mumps, which work such mischief among these same children—a fact which by itself proves the illogical nature of the education given. Similarly in the tropics I have seen a large class of coloured children, almost all of whom were suffering at the time from fever or enlargement of the spleen, being taught the dates of accession of the Plantagenet kings.

We all know how often sanitation receives only the crumbs which remain at the bottom of the public pocket after all the other departments have been well fed—the final triumph of fakirism.

But we must not blame the general public alone. We are familiar with the manner in which individual medical men give their services, not only to medical science, but for the gratuitous treatment of the poor; yet nevertheless the medical profession as a body possesses little influence or power in public affairs. It is a body without a head. It does not take a high enough stand with the public regarding scientific and sanitary matters. The duty of the profession does not lie merely in teaching and in the cure of the sick, but in everything that appertains to the health of the people. Yet it is apt to be dominated, not by this lofty ambition, but by other ideals; and it therefore seldom bestirs itself regarding...
its higher duties. Can we wonder then that governments also are apt to neglect the same duties?

Several high officials have told me that medical men do not often become good administrators. This is probably due to the fact that governments seldom take enough care in the selection of their administrative medical officers. I have seen many able men in such posts, but others who were not fitted for them. The head of a large sanitary or medical department should possess a full knowledge of the recent scientific and practical advances in his subject. Too often we find officials who have been promoted merely on account of seniority, or in consequence of self-service; men who express contempt of these recent advances because they know nothing about them; who have no ideas, and who make no efforts. Such men, when taxed with defects in their department, always complain that the Government does not grant enough funds. But they are the responsible heads of those departments; and if their advice is neglected they should resign their post.

In 1730 Dr Thomas Fuller (Exanthelmatologia, Charles Rivington, London—quoted by W. S. Thayer) wrote: "Can any man, can all the Men in the World, tho' assisted by Anatomy, Chemistry, and the best Glasses, pretend positively and certainly to tell us, what particles, how sized, figured, situated, mixed, moved, and how many of them, are requisite to produce a quartan ague, and how they specifically differ from those of a tertian . . .?" We are now able to tell all these things. They have been written in hundreds of books, and are familiar to thousands of students. Those who belittle the powers of science are not always, perhaps, the wisest of men.

The history of malaria contains a great lesson for humanity—that we should be more scientific in our habits of thought, and more practical in our habits of government. The neglect of this lesson has already cost many countries an immense loss & life and in prosperity.
CHAPTER II
SUMMARY OF FACTS REGARDING MALARIA
Suitable for Public Instruction

9. The Parasites and the Fever. — Malaria, or Malarial Fever, is also known by the names Paludism, Marsh Fever, Jungle Fever, Ague and Periodic Fever. It is often called by local names such as Country Fever, West African Fever, Burma Fever; and varieties of it are called Intermitting Fever, Remittent Fever, Pernicious Fever and Blackwater Fever.

Malarial fever occurs more or less in all warm climates, especially in the summer, after rains, and near marshy ground; and causes a quarter or more of the total sickness in the tropics.

It is caused by enormous numbers of the minute parasites of the blood called Plasmodia.

These parasites are introduced into the blood through the proboscis of certain species of the mosquitos called Anopheles.

On being introduced, each parasite enters one of the red corpuscles of the blood, in which it lives and grows.

On reaching maturity each parasite produces a number of spores which escape from the containing corpuscle, and enter fresh corpuscles; and this method of propagation may be continued indefinitely for years.

Thus, though only a few hundreds or thousands of the parasites may have been originally introduced through the mosquito’s proboscis, their number rapidly increases until as many as some millions of millions of them may exist in the blood.

At first, while the number of parasites is still small, the...
Infected person may remain apparently well. When, however, the number is large enough, he begins to suffer from fever. The parasites tend to produce their spores all at the same time; and it is at the moment when these spores escape that the patient’s fever begins.

The fever is probably caused by a little poison which escapes from each parasite with the spores.

After from six to forty hours or more this poison is eliminated from the patient’s system; and his fever then tends to leave him.

In the meantime, however, another generation of parasites may be approaching maturity; and may cause another attack of fever like the first; and so on, indefinitely for weeks or months. In this manner the attacks of fever follow each other at regular intervals.

But it often happens that before one attack has entirely ceased another one commences; so that the attacks overlap each other, and the fever is continued.

After a time, even without treatment, the number of parasites may decrease, until not enough of them are left to produce fever; when the patient improves temporarily.

It generally happens, however, sooner or later, that the number of parasites increases again; when the patient again suffers from another series of attacks.

Such relapses are frequently encouraged by fatigue, heat, chill, wetting, dissipation and attacks of other illness.

They may occur at intervals for a long time after the patient was first infected, and after he has moved to localities where there is no malaria.

It is probable that as long as one parasite remains alive in the patient’s blood he may remain subject to such relapses.

Besides fever, the parasites often produce anaemia and enlargement of the spleen, especially in patients who have suffered from many relapses.

Death is sometimes caused by sudden and grave symptoms.
Chief among these are the symptoms known as Blackwater Fever, or Haemoglobinuria, which generally occurs in old and neglected infections.

Death is also often caused during the course of a malarial infection by other diseases, such as pneumonia or dysentery, acting upon a constitution already enfeebled by the parasites.

If the patient survives, the parasites tend to die out of themselves, without treatment, after a long period of illness—leaving him more or less "immune."

The parasites are at least of three kinds, which can easily be distinguished in blood placed under the microscope. These are (1) the parasite which produces its spores every three days and causes quartan fever; (2) the parasite which produces its spores every other day, and causes tertian fever; (3) parasites which cause the so-called malignant fever, in which dangerous complications most frequently occur.

If a little blood containing any one of these species of parasites is taken from a patient, and is then injected into a vein of a healthy person, the latter will almost certainly soon become infected with the same species of parasite.

Closely similar parasites are found in monkeys, bats, squirrels and birds.

As proved by centuries of experience, cinchona bark, from which quinine is made, possesses the power of destroying the parasites and curing the infection. But it will not generally destroy all the parasites in the body unless it is given in sufficient doses and continued for several months; and as long as a single parasite remains alive in the blood, infection is continued and the patient may be subject to relapses. At least five grains (1/3 gramme) of sulphate of quinine should be taken by an adult patient every day without fail for four months; but he should consult a medical man regarding details of the treatment.

10. The Mode of Infection.—Besides these forms of the...
SUMMARY OF FACTS REGARDING MALARIA

Malaria parasite which produce spores in the human body, there are other forms, male and female.

When certain species of the mosquito called Anopheles happen to feed on a patient whose blood contains the parasites of malaria, these are drawn with the blood into the insect's stomach.

If the sexual forms of the parasites are present, these undergo certain changes in the mosquito's stomach; the female pass through its wall; and finally fix themselves to its outer surface—that is, between the stomach and the skin of the insect.

In this position they grow largely in size, and after a week, in favourable circumstances, produce a number of spores.

The spores find their way into the insect's salivary glands. This gland secretes the irritating fluid which the insect injects through its proboscis under the human skin when it commences to feed; and the spores can easily be found in the fluid by the microscope.

Thus when a proper species of Anopheles, which has more than a week previously fed upon a patient containing the sexual forms of the parasites of malaria, next bites another person, it injects the spores, together with its saliva, under his skin—that is, generally into his blood.

These spores now cause, or may cause, infection or reinfection in this second person, as described at the beginning of this summary.

Numerous birds and men have been infected experimentally in this manner.

Thus the parasites of malaria pass alternately from men to certain mosquitoes, and back from these mosquitoes to men. A very large number of parasites are known which pass in this manner from one animal to a second animal which prey on the first; and back again from the second animal to the first.
THE MODE OF INFECTION

It is not known with certainty when and how this process first commenced; but probably all such parasites were originally free living animals, which by the gradual evolution of ages acquired the power of living in other animals.

Thus also, it is evident that malarial fever is an infectious disease which is communicated from the sick to the healthy by the agency of certain mosquitoes.

From the time of the ancients it has been known that malarial fever tends to be most prevalent in the vicinity of marshes.

The parasites of malaria have never been found in the water or silt of marshes; nor in decaying vegetation; nor in the soil. Attempts to produce infection by these have always failed. But the Anophelines which carry the parasite breed in marshes and in marshy pools and streams.

Rising from these marshes, they enter the adjacent houses and feed on the inmates, mostly at night; biting first one person and then another; and living for weeks or months.

If an infected person happens to be present in any of these houses, the infection is likely to be carried by the Anophelines from him to the other inmates, and to neighbouring houses.

Thus the whole neighbourhood tends to become infected, and the locality is called "malarious."

In such localities, it is easy to find the parasites of malaria in the Anophelines of the proper species; even in as many as 25% or more of them.

Such Anophelines when taken from a malarious locality to a healthy one (e.g., from the Campagna near Rome to London) will still infect healthy persons whom they have been caused to bite.

So also, in malarious localities, the Anophelines bite the healthy new-born children, and infect many of them.

Such children, if not thoroughly treated, may remain infected for years; may become anaemic and possess enlarged...
4. SUMMARY OF FACTS REGARDING MALARIA

Spleens; and may spread the infection to others. Later, however, at the age of twelve years or more, the survivors tend to become "immune."

In many malarious localities almost every child has been found to contain the parasites of malaria, or to possess an enlarged spleen.

In such a locality therefore, the infection is constantly passed on from the older children, or from adults, to the new-born infants; so that the locality may remain malarious for years, or for centuries.

Similarly, a new-comer arriving in such a locality is very likely to become infected, especially if he sleeps in an infected house even for one night.

A locality is said to be malarious only when healthy persons become infected in it; not when persons who have become infected elsewhere happen to reside in it.

A locality is malarious only when it contains persons already infected with the parasites, and also sufficient numbers of the proper species or varieties of Anophelines to carry the infection to healthy persons.

The chances of infection tend to be great in localities where there are already numerous infected persons, not treated with quinine; or where there are numerous Anophelines of the proper species, not prevented from biting.

Conversely, the chances of infection tend to be less where infected persons are excluded, or properly treated with quinine; or where the Anophelines are few in number, or are prevented from biting.

II. Facts about Mosquitoes—Gnats, which in the tropics are commonly called mosquitoes, belong to the zoological family of insects known as the Culicidae (from the Latin culex, a gnat). They are distinguished from other insects by a number of characters; and always possess only one wing on each side, and a long proboscis.
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Like that of other insects, their life is divided into four
stages, the egg; the larva (or caterpillar); the pupa (or chrysalis);
and the imago (or adult, winged insect).

The egg is laid on water or near it, and in warm, moist
weather hatches out in a day or two.

The larva is entirely aquatic, and always lives in water. It
swims and dives by means of paddles and hairs, and feeds on
various aquatic organisms. It cannot, however, breathe under
water, but must always rise to the surface in order to obtain
air. After a week or more it becomes a pupa.

The pupa still remains in the water, generally floating on the
surface. After two days or more its skin cracks, and the
imago emerges.

The imago remains standing for a little while on the empty
floating skin of the pupa, and then flies away.

Both males and females are able to suck fluids through the
proboscis. As a rule the male feeds only on the juices of
plants; but the female sucks the blood of men, beasts, birds
and reptiles. The female often returns to water every few
days in order to lay her eggs, of which she may deposit several
hundreds at a time; and then seeks another meal.

Female gnats have been kept alive in captivity for months.

In unsuitable weather both males and females may take
refuge in damp places such as cellars, wells, out-houses and
woods, where they may remain for months until better con­
titions prevail.

As a rule gnats, like other animals, tend to remain in the
locality where they were born; but a few may occasionally
stray to the distance of half a mile or more from their breed­
ing places. If, however, plenty of places where they can obtain
food exist near at hand, there is no reason why they should
travel further for it. They must also remain near water to
drink and to lay their eggs in.

Gnats are generally favoured by warm weather, by plenty
of water suitable for their larvae, and by abundance of food.
They tend to be diminished by various kinds of bats, birds, fish, insects and spiders which devour them or their larvae. During its life, a single gnat may succeed in biting many persons or animals, and in propagating diseases amongst them. The family of Culicidae or Gnats is divided into many sub-families and genera, and contains some five or six hundred known species.

Although all these species have many habits and structural characters in common, yet they all differ in small details. These have been described at length in a number of special books written on the subject.

In the tropics, as a broad general rule, the gnats which most concern human beings belong to the groups called Culex, Stegomyia and Anophelines.

*Culex pipiens* is a very common gnat in Europe, and allied species are found almost everywhere in the tropics. The larvae occur principally in tubs, barrels, cisterns and other vessels containing water, in stagnant ditches, garden pits, holes in rock and trees, and so on. They possess a long breathing tube close to the tail fins; and that at the surface of the water with the end of this tube attached to the "surface film," and the head hanging downwards. When disturbed, they wriggle at once to the bottom. The adult insects generally present a uniform grey appearance, with pale yellowish bars across the back of the abdomen, and plain unspotted wings. They bite almost entirely in the evening and night, and principally indoors (in the tropics). The parasite which causes elephantiasis, namely the *Filaria bancrofti*, is carried by them or allied species in a manner very similar to that in which the Anophelines carry the parasites of malaria.

*Stegomyia calopus* and allied species are very common in the tropics, but much less so in temperate climates. The larvae breed in much the same places as those of *Culex*, but more frequently in vessels. Any old biscuit tin or oil tin, flower-pot, broken bottle and crockery, tub or barrel, choked drain, roof
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in which rain or other water has collected, is almost sure to contain them, and they frequently occur in holes in trees and in certain plants. They possess a short stubby breathing tube, and float head downwards, like the larvae of Culex. The adult insects are more or less striped or speckled black and white, and have plain unspotted wings. They bite chiefly in the daytime, and often abound in woods and in the shade of trees. In America Stegomyia falxata carries yellow fever.

The Anophelines consist of about one hundred and twenty known species, some of which carry malaria and are always found in malarious places. The larvae occur chiefly in water on the ground, particularly in water which stands or flows amongst grass or water weeds. Thus they abound in the weedy margins of rivers, streams, lakes and ponds; in small sluggish streams and streamlets; in water courses, drains and gutters choked with weeds; in pools of rain water lying on grass; in pits from which earth has been removed, such as the "borrow pits" by the side of railway embankments; in cisterns and pits used for watering gardens; in ornamental waters; in hollows in rocks; and in water at the bottom of boats, etc. Thus while the larvae of Culex and Stegomyia occur in the small collections of water which abound in and around houses, on the other hand the Anophelines are principally marsh mosquitoes—owing to which malaria is generally more or less connected with marshy conditions, and is called Marsh Fever, or Paludism. The larvae feed chiefly on the surface of the water—on which they float like sticks, and not with the head hanging downwards. When disturbed they swim away backwards on the surface, and sink to the bottom only when much alarmed. They have no breathing tube, like those of Culex and Stegomyia. The adults are speckled brown and white, or black and white, and generally the wing are not plain, but possess three or four black markings along or near the front border. When the insect is quiet at rest on a wall, the tail projects outward at an angle from the
wall; whereas the Culex and Stegomyia sit with the tail hanging downwards, or even nearly touching the wall. All these facts enable anyone to distinguish at sight both the larvae and the adults of Anopheline from those of Culex and Stegomyia. Anophelines bite chiefly at night or in the dusk—owing to which the malarial infection is generally acquired at night. They enter houses, but also bite in the open in spots sheltered from wind.

12. Personal Protection.—If they can avoid it, people should not go to live in known malarious places, nor in the vicinity of marshes, nor close to an infected native population. Even in such, however, the chances of infection can be much reduced by the careful use of mosquito nets. The net should not have the smallest hole. It should be hung inside the poles, when these are provided, and not outside them. It should be tucked under the mattress all round, and should never be allowed to hang down anywhere to the floor; and it should be stretched tight, in order to allow every breeze to enter, and should not be hung in loose folds, which check ventilation.

Those who can afford it should protect the windows of the house with wire gauze, and provide the doors with automatic closing arrangements. It is especially advisable to protect a room, or a part of the veranda, for sitting in during the day or evening.

Fans and electric fans, not only drive away mosquitos, but also keep the body cool, comfortable and vigorous, even in great tropical heat.

Where there is great danger of malaria, five grains (1/3 gramme) of quinine should be taken regularly every day just before breakfast; but it is advisable to take a double dose at least once a week—say, on every Sunday. In such localities, the hands and feet may also be protected by gloves and boots; but these cannot always be endured owing to the heat; and it is preferable instead to carry and use
constantly a palm-leaf fan, with which mosquitoes can be driven off and the body kept cool.

2. A small butterfly-net of white (not green) muslin may be kept in the house for the purpose of catching troublesome mosquitoes during the day; and the servants may be taught to use it. It may sometimes be easier to kill all the mosquitoes in a room in this manner than by fumigation.

Mosquito traps consist of boxes lined with black cloth. Attracted by this colour mosquitoes enter the box for refuge during the day. The lid or shutter is then suddenly closed and the insects within are killed by a little ammonia or chloroform poured into the box through a protected opening. Or, the lid can be made to slide down to the bottom of the box in such a manner as to crush the insects.

To fumigate a room thoroughly for mosquitoes all the chinks in the doors and windows should be closed by pasting paper over them. Then burn the culicide as follows (Sir Robert Boyce):

1. Sulphur—Allow 2 lbs. of sulphur to 1,000 cubic feet.

   Use two pots, place them in a pan containing 1 inch of water to prevent damage, and set fire to the sulphur by means of spirit.

   Duration—Three hours.

2. Pyrethrum—Allow 3 lbs. to 1,000 cubic feet, and divide amongst two or three pots, using the same precautions as with sulphur.

   Duration—Three hours.

3. Camphor and Carbolic Acid—Equal parts camphor and crystallised carbolic acid are fused together into a liquid by gentle heat. Vapourise 4 ozs. of mixture to each 2,000 cubic feet; this can be done by placing the liquid in a wide shallow pan over a spirit or petroleum lamp; white fumes are given off. To avoid the mixture burning, the fumes should not come in close contact with the flame of the lamp.

   Duration—Two hours.
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Remember that sulphur tarnishes metal work and injures pianos, sewing machines, chronometers, telephones, etc.

The camphor-cathartic mixture is one of the most agreeable and effective of the various agents.

Many mosquitoes may be killed, without troubling to cover the chinks with paper, simply by picking up and destroying the stupefied insects near the windows after the fumigation.

The householder should always take care that no stagnant water is allowed to remain anywhere in his premises in cisterns, drains, gutters, tubs, jugs, flower-pots, guards, broken bottles and crockery, old tins and other rubbish, or in holes in trees, or in certain plants such as wild pineapple—in all of which mosquitoes are apt to breed. If the water cannot be emptied out, the larvae of the mosquitoes in it may be destroyed by pouring a little kerosene oil, or in the case of drinking water, a little eucalyptus oil, upon the surface. This should be done once a week; and the householder should make it a habit to inspect his premises for this purpose every Sunday. Cisterns and tubs containing drinking water should be kept screened in such a manner as to prevent mosquitoes laying their eggs on the surface of the water. If he follows this advice the householder will generally obtain a great reduction in the number of the insects in his house. If, however, the plague continues, he should appeal to the local sanitary authorities.

It is extremely dangerous to sleep in a house which is occupied, or has recently been occupied, by infected persons, especially native children: or in or close to an infected native village.

13. Public Prevention.—As a broad general rule, malaria causes a quarter or more of the total sickness in the tropics. Malaria can always be greatly reduced, or may even be exterminated, in any locality. Large marshes in populous places must be drained, deepened or filled up.
A proper permanent organisation must be established for dealing with the smaller breeding-places of Anophelines, and in distributing quinine—especially to infected children. Other measures may be adopted where called for.

The cost is likely to be more than recouped by saving in life, labour, invaliding, medical attendance and hospital accommodation.

The campaign will remove other mosquito-borne diseases as well as malaria, and will tend to improve general sanitation in the locality where it is undertaken.
CHAPTER III
THE FUNDAMENTAL OBSERVATIONS AND EXPERIMENTS

14. The Parasites cause the Disease. — Having studied the history and a general outline of our subject, we must now examine the fundamental observations and experiments in greater detail. It is advisable to begin with the evidence which proves that the parasites are really the cause of the disease.

(I) The parasites are not found in those who have not suffered from malarial disease. Laveran discovered the parasites of malaria at Constantine, Algeria, in 1880. Since then the blood of hundreds of thousands, possibly of millions, of patients suffering from various diseases must have been examined, during the ordinary course of clinical work, in the civilised countries of the globe. Yet I have never heard of a single case in which Laveran's parasites are reported to have been found by a competent observer in persons who have never had malarial fever. For example, in Britain, which is now practically non-malarious, they are never seen in the vast numbers of hospital patients. In only two cases that I know of have they been observed in men who have never been out of this country, and both these patients suffered from the characteristic symptoms of malarial fever. In the tropics they are often found in persons, especially children, who have no fever at the moment of examination; but that is another matter. Such persons generally show other symptoms of the disease; and I know of no case which has been proved to

\[ \text{See the articles by Copeland and Smith [1906], and Easton [1909], and page 214.} \]
The parasites can always be found in a large proportion of malaria cases. The amount of blood examined under the microscope is extremely small compared with the total amount of blood in a patient's body; so that if the parasites are not very numerous they may easily be overlooked, even by a skilled observer. Moreover, many cases come under observation only after the parasites have largely diminished in number; or do not remain under observation long enough for a thorough search for the parasites to be made. Hence we can scarcely expect to find the organisms without fail in every patient. But the experience of thirty years proves that the percentage of successes depends almost entirely on the care with which the search is made.

Since Laveran's discovery the parasites have been found by innumerable observers in large proportions of their cases. To mention a few—Laveran himself observed them in 432 out of 480 cases in Algeria [1881, p. 30]; W. S. Thayer and J. Hewetson in nearly all of 333 hospital in-patients in Baltimore [1895]; A. Billet in all of 395 cases in Algeria [1901]; W. Duggan in all of 400 cases in Sierra Leone [1897]. In Secunderabad, India, without attempting exhaustive search, I found the parasites in 60 out of 112 cases [1896]. Similar figures are given in most papers on the subject, and the matter has now become a commonplace of clinical medicine.

The patient's fever begins at the moment when the spores of the parasites are liberated. This important fact was discovered by C. Golgi at Pavia, towards the end of 1885, and proves that the fever depends upon the parasites. In a masterly paper [1886] the author describes his study of forty cases of malaria, mostly quartan. In twenty-two of these he followed the development of the parasites in the peripheral blood pari passu with the progress of the malady; and he gives five of the cases in detail as examples of his finding.
The first classical case was that of a woman suffering from untreated simple quartan fever (attacks occurring every three days). Her blood was examined at 11:30 A.M. on the 2nd November, at the moment when her fever was expected to commence, and was found to contain a few full-grown parasites, and many other ripe ones full of spores. The attack commenced at noon while the blood was being examined. Next day there was no fever, and the blood contained only young parasites. The next day (3rd November), there was still no fever, but the young parasites had now grown larger and occupied 3/4ths to 4/5ths of the containing haematids. On 5th November, three hours before the expected attack, the blood again contained nearly mature parasites, some with commencing spore formation. An hour before the attack these were increased in number. The attack then commenced at noon. Three hours later only a very few sporulating forms occurred; and five hours after the attack all of them had disappeared, being again replaced by numerous young parasites. On 6th and 7th November the same development of the parasites occurred as on the 3rd and 4th; and on 8th November there was a third attack of fever with parasites as on the 3rd and 3th. Quinine (1.5 grammes) was given on the 10th; and a fourth attack of fever occurred at 5:30 P.M. on 11th November.

The next case described by Golgi was one of "double quartan," that is, two sets of parasites reaching maturity on different days—one set giving severe attacks on 24th, 27th and 30th November, and the other mild attacks on the 23rd, 26th, 29th, and so on. The parasites of each set developed just as in the first case, independently of those of the other group. The third case was at first triple quartan; then, owing to the dying out of the different sets of parasites, double, and lastly single, quartan—the parasites always undergoing the same cycle of development. The fourth and fifth cases need not be described here.

These beautiful studies were quickly confirmed by W. Osler.

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(1886, 1887) by many Italian workers, and by Mannberg. Such facts have also now become a commonplace of clinical medicine.

The different types of malarial fever are caused by different species of parasites. Since the time of the ancients clinicians have been acquainted with three different types of fever, the quartan, the tertian, and the irregular or malignant type. This variation of type was equally surprising and inexplicable until Golgi, after elucidating quartan fever, commenced a study of tertian, and showed that it is produced by a parasite which is morphologically different from the quartan parasite, and reaches maturity every two, instead of every three, days. As in quartan, however, the patient's fever begins at the moment when the spores are liberated (1886, 1887). Golgi also suggested that the third variety of fever is associated with a third variety of parasite—that which produces the well-known "crescents," and this was proved to be the case by P. Canalis (1890) and Marchisiana and Celli (1895) who made a detailed study of the organism. Numerous confirmations followed, and the observations are now in general use for clinical diagnosis.

Both parasites and the fever may be reproduced in healthy persons by the inoculation of infected blood. This has been done successfully in fifty-one cases, which will be described in the following section.

Both parasites and the fever may be reproduced in healthy persons by the bite of infected mosquitoes. This has been done successfully in thirty-six cases, which will be described in section 17.

These facts are more than sufficient to prove that the parasites cause the disease. Additional but less precise arguments are—

(2) The severity of the illness depends roughly on the number of parasites present. First suggested by Laveran and Golgi (1886), this theorem is now generally accepted, but rather on the grounds of common experience than on precise estimations.
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(8) Quinine reduces both the parasites and the fever. This theorem, first suggested by Laveran, is now accepted everywhere, but still requires more precise study.

(9) Certain secondary symptoms are caused by the accumulation of the parasites in certain organs. As frequently proved in the case of the malignant parasites.

(10) Both the parasites and the fever tend to disappear in a locality if the cratering Anopheles are greatly reduced in number.

As shown in many places, notably Ismailia.

15 Experimental Blood Inoculations.—Three classical experiments, commenced independently of Laveran’s discovery, and giving independent proof of a contagion virus in malaria, are of fundamental importance.

The first experiments were those of A. Dochmann [1886]. One drop of the contents of vesicles of Herpes labialis of a boy suffering from quartan was inoculated subcutaneously into a healthy man on 8th February (9) 1886. The man had rigors and fever the same evening and on 11th February, and malaise on 14th February, no symptoms occurring in the intervals. Subsequently three men were similarly inoculated with herpetic serum from a girl with quotidian. This was followed by five days’ quotidian in one of the men, and none in the others. Lastly, a girl was similarly inoculated on 12th April, and had fever on 14th and 15th April. These appear to have been no incubation period, and I agree with Laveran that the cases must be rejected. The admissible cases are now given and numbered for reference.

Case 1. Gerhardt [1886].—Source, quotidian fever; 1 c.c.m. of blood taken at end of rigor and injected subcutaneously into B. S., on 11th August 1885. Subject had slight fluctuations of temperature 23rd to 26th August, and severe rigor and fever on 27th, 28th, 29th August. Quinine 2 grams on 30th; recovery after two days.

Case 2. Ibid.—Source, quotidian fever; blood (9 quantity)
taken during attack, and inoculated into K. G. at 2.15 P.M. on 4th July. Subject attacked at 6 P.M. on 10th July, and again at about 3 P.M. on 11th, 12th, 13th, 17th, 23rd, 25th, 28th, 29th, 30th (severe), 31st July. Quinine 2 grams daily, 1st to 6th August. Recovery followed.

Note.—The author appears not to have heard of Laveran's discovery; but his work was careful and good.

Case 3. Marchalav and Ceii [1885].—Healthy subject was inoculated subcutaneously with 0.5 c.cm. of blood taken from quotidian cases during attack on 18th July and 15th August (?) 1884. Again, intravenously with 0.5 c.cm. taken from a quotidian case during rigor on 21st August. Again, intravenously, with 1 c.cm. taken from a case of double tertian (malignant) six hours before attack, on 26th August. Subject had strong rigor one hour after this last injection, and further attacks on 27th, 30th August, and 1st, 3rd September, when quinine was given. Isolated attacks occurred up to October.

Case 4. Ibid.—Subject, who had previously had malaria and was said to have been cured, was inoculated intravenously with 0.6 to 3.0 c.cm. of blood from various cases on 31st August, 4th and 6th September. Left hospital. Returned to hospital with fever on 10th September. Daily attacks like those of the source of blood inoculated on 6th September, the period of incubation being said to be seven days.

Case 5. Ibid.—Healthy subject inoculated with 1.0 c.cm. of blood from three cases, subcutaneously or intravenously on 6th, 9th and 13th September. Strong rigor on 20th September, and fever till 23rd.

Note.—Confused experiments. Type of parasites not clearly seen (before Golgi's work). Mariotti and Ciarrochi, in whose clinics the work was done, also reported it.
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Case 6. Gualdi and Antolisi [1889, No. 225]. Source reputed to be quartan; 3 c.cm. injected intravenously. Subject attacked ten days later with malignant parasites.

Case 7. Ibid.—Same source, dose and injection. Another subject. Attacked twelve days later, also with the malignant parasites.

Note.—In these two cases the quartan of the source seemed to have produced malignant in the subjects; by the authors stated later [1889, No. 264] that the source was subsequently found to contain malignant as well as quartan parasites, the former also being observed microscopically.—so that the result of the experiments was not surprising.

Case 8. Antolisi and Angelini [1889, Nos. 226, 227].—Source, mild tertian; blood (? quantity) taken at beginning of fever; injection intravenous. Subject attacked with fever after eleven days; mild tertian parasites.

Case 9. Ibid.—Same source as previous case; 1.5 c.cm. of blood taken at the same time; injection intravenous. Subject attacked almost at same hour as previous case. The same parasites.

Case 10. Gualdi and Antolisi [1889, No. 264].—Source, quartan; 3 c.cm. of blood injected intravenously. Subject attacked after twelve days; quartan parasites.

Case 11. Ibid [1889, No. 274].—Source, malignant parasites with apyrexia and (?) crescents only; 2 c.cm. of blood, intravenous. Subject attacked with irregular fever on ninth day, and asexual malignant parasites on tenth day. Crescents on eighteenth day.

Case 12. Di Mattei (1891, No. 121).—Source, malignant; (? quantity of blood injected intravenously. Subject, a case of quartan which had (?) recovered spontaneously. A few days
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Later small unpigmented asexual forms, and crescents twenty-five days after inoculation.

**Case 13.** Ibid.—Source, quartan; (?) quantity of blood, intravenous. Subject, a case containing crescents only. Subject attacked after fifteen days with quartan parasites, the crescents diminishing in number.

**Note.**—These two cases show that a second species of parasite can be added to a previous invasion.

The disappearance of the crescents in **Case 13** need not have been due to the new invasion.

**Case 14.** Calandruccio [1891]—Source, quartan; 1 c.cm. of blood, subcutaneously injected on 1st December 1890.

Subject, the author himself, attacked with quartan on 18th December; relapses after two and three months.

**Case 15.** Ibid.—Source, a case showing (1) only crescents; 15 c.cm. subcutaneous. Subject, the author after recovery from previous infection. After fifteen days was attacked by severe rigor and fever, and then crescents after three days. No young asexual forms found. Several relapses.

**Case 16.** Ibid.—Source, quartan; 1 c.cm. of blood (?) subcutaneous. Subject attacked after twelve days with quartan.

**Case 17.** Ibid.—Source containing only crescents; 15 c.cm. subcutaneous. Subject the same as in previous case, four months later. Crescents found in spleen on eighteenth day, and in peripheral blood on twentieth day. No asexual forms.

**Note.**—Author seems to have believed with Grassi and Feletti that the crescents were a species by themselves (Lazlfrania).

**Case 18.** Bein [1891].—Source, mild tertian. Blood drawn by leeches, taken out by a syringe, and injected to the amount of 2 c.cm. in this and the three following cases. Subject attacked on twentieth day with mild tertian parasites.
Case 19. Ibid.—Source, mild tertian. Same procedure. Subject attacked on twelfth day with mild tertian parasites.

Case 20. Ibid.—Source, mild tertian. Same procedure. Subject attacked on tenth day with mild tertian parasites.

Case 21. Ibid.—Source same as in last case. Same procedure. Subject attacked on tenth day with mild tertian parasites.

Note.—Four attempts failed. The injection was intravenous in one case, subcutaneous in the others. The type of fever was not always the same as that of the source, being sometimes simple and sometimes double tertian; but this is easily explicable. The same parasite was always found in the subject.

Case 22. Baccelli [1892].—Source, tertian; 3 c.cm. of blood injected intravenously. Subject attacked with double tertian parasites after six days.

Case 23. Ibid.—Source, quartan; 4 c.cm. of blood containing few parasites, intravenously. Subject attacked with single quartan parasites after eleven days.

Case 24. Sacharoff [1894].—Source, malignant. Blood drawn by leeches, which were kept on ice for four days; 1/4 c.cm. of this blood injected subcutaneously on 4th October (?) 1893. Subject, the author himself, had rigor and fever on 16th and 17th. Malignant parasites found on latter date.

Note.—This experiment was made during the course of study of the vitality of the parasites in leeches kept at freezing point. A second experiment, with blood kept thus for seven days, failed.

Case 25. Bigianni and Bastianelli [1894].—Source, malignant; 2 c.cm. taken at close of paroxysm; numerous parasites. Subject attacked after (?) three days with the same parasites.
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Case 26. Ibid.—Source, malignant; 1 c.cm. of blood with moderate number of parasites, at close of paroxysm. Subject attacked after (7) four days with the same parasites.

Case 27. Ibid.—Source, malignant; 2 c.cm. of blood with moderate number of parasites(? scanty). Subject attacked after five days with the same parasites.

Case 28. Ibid.—Source, malignant; 1/5th c.cm. with (?) numerous parasites. Subject attacked after four days with same parasites.

Case 29. Di Mattei [1895].—Source, quartan; 2 c.cm. subcutaneous, on 14th August (? 1894. Subject attacked with simple quartan on 1st September (sixteen days).

Case 30. Ibid.—Same source and same injection on same date. Subject attacked with simple quartan on 25th August (eleven days).

Note.—Two other cases, injected subcutaneously with 0.5 and 1.0 c.cm. failed.

Case 31. Ibid.—Source, malignant; 2 c.cm. of blood from epistaxis injected subcutaneously in two places on 18th September. Subject attacked with malignant parasites on 3rd October. Fever on 3rd, 4th, 5th, 9th, 10th October. Crescents on 11th; quinine on 16th. Fever again on 17th; quinine; recovery.

Note.—In this paper author re-describes his earlier experiments [1895], and also describes eight negative attempts to transfer the malaria of birds from bird to bird or bird to man, and four negative attempts to infect birds from men.

Case 32. Bignami [1898].—Source, malignant; less than one drop of blood, subcutaneous. Subject attacked after six days with the same parasites.

Case 33. Ibid.—Similar to the above. Subject attacked after ten days with the same parasites.
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Case 36. Mannahang (1905). Source, benign tertian; 0.2 c.c.m. of centrifugated blood taken during paroxysm; sediment injected subcutaneously. Subject attacked after twenty-one days with the same parasites.

Case 37. Celli and Sartori (1897). Source, quartan; 4 c.c.m., subcutaneous. The same parasites in subject after twenty-five days.

Case 38. Ibid. Source, quartan; 4 c.c.m., subcutaneous. The same parasites after twenty-five days.

Case 39. Ibid. Source, quartan; 4 c.c.m., subcutaneous. The same parasites after twenty-five days.

Case 40. Ibid. Source, malignant; 1 5 c.c.m., subcutaneous. The same parasites after thirty days.

Case 41. Ibid. Source, malignant; 1 5 c.c.m., subcutaneous. The same parasites after thirty days.

Case 42. Ibid. Source, malignant; 1 5 c.c.m., subcutaneous. The same parasites after thirty days.

Case 43. Ibid. Source, malignant; 1 5 c.c.m., subcutaneous. The same parasites after thirty days.

Note.-In these six last cases the blood was mixed with sera of horse, buffalo or cattle before being injected, in the hope of immunising the subject.

Case 44. Elting (1899). Source, benign tertian; 3 c.c.m. of blood containing half-grown parasites injected intravenously on 7th August ( ) 1899 at ( ) Baltimore. Subject had a slight rise of temperature next day and sharp rise to 399° C. on 10th. Benign tertian parasites next day.

Case 45. Ibid. Same source; 3 c.c.m. taken and injected the same day. Fever on fifth day; benign tertian parasites on the previous day.

Case 46. Ibid. Source, malignant, with numerous asexual forms and a few sexual ones. Blood injected ( ) 1 5 to 40 c.c.m.
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(1) intravenously on 28th August (I) 1882. Fever night of 29th to 31st; malignant parasites on 31st; crescents on 6th September.

Case 44. Ibid.—Same source, method and date. Asexual malignant parasites found in subject 1st September with commencing fever. High fever on 3rd, and crescents on 8th.

Case 45. Ibid.—Same source and method. Inoculation of subject 29th August, followed by a short rise of temperature in 12 hours, after which there was no fever till 3rd September. Asexual malignant parasites on previous day (4th), and crescents on 11th.

Case 46. Ibid.—Source, malignant—Case 43 above. Blood (?) quantity taken a few days after appearance of asexual forms, and (?) hour injected on 1st September. Asexual malignant parasites found on third day after injection, and thirty-two hours before first rise of temperature. Crescents on ninth day.

Case 47. Ibid.—Same source, method and date. Fever on 4th September, and asexual malignant parasites on same day. Crescents on 11th.

Case 48. Ibid.—Source, malignant—Case 46. Blood contained numerous asexual forms, and 15 ccm. injected intravenously on 9th September. Asexual malignant parasites on 15th; fever on 24th; crescents on 29th.

Case 49. Ibid.—Two sources—malignant and benign tertian. Two or three drops of blood containing only malignant parasites injected subcutaneously (?) date. Next day 4 ccm. from benign tertian case injected intravenously. Short rise of temperature two hours after second injection; then normal for five days. Fever seventh day after first injection, and malignant parasites next day. Benign tertian parasites ten days after second injection; both flourished together. Crescents seventeenth days after first injection.

Case 50. Ibid.—Two sources—benign tertian and malignant
Blood from former, 4 c.cm. containing numerous parasites, injected subcutaneously. Slight rise of temperature six hours later. Marked fever on seventh day, and benign tertian parasites on tenth day.

On the third day after first rise of temperature (? ten days after first inoculation) the subject was inoculated with (?) quantity of blood containing numerous asexual malignant parasites — intravenously. These were recovered in blood of subject four days later, together with numerous tertian parasites. Fever suddenly ceased eighteen days after first injection; then seven days apyrexia with only one or two tertian parasites each day. But twenty-six days after first injection, quotidian fever with both parasites began. Quinine and cure.

**Case 1.** Rosenau, Parker, Francis and Beyer (1904).—At Vera Cruz. Source, double benign tertian ("heavy" infection); 2 c.cm. of blood containing numerous parasites — intravenously into subject at 2 p.m. on 6th November 1903. Slight reaction within an hour. Typical fever and parasites at 7 a.m. on 10th November, double infection (section 9). This closes the list of positive experiments, but four important negative ones with blood containing (?) only sexual parasites remain to be recorded.

**Negative Case 1.** Thayer (1898, p. 75).—Source, a patient, convalescent from first attack, had had quinine for four days, during which none but crescentic and ovoid forms were found in the peripheral circulation. A hypodermic syringe full of his blood was injected into median basilic vein of subject in August (? year). The latter was carefully observed for five weeks, but never showed fever or parasites.

**Negative Case 2.** Elting (1899).—Source, malignant, with crescents and asexual forms, treated for eight days with four hourly doses of 5 grains (0.315 grams) of quinine, until only the crescents were left. Subject, injected intravenously with
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3 to 3.5 c.c.m. of blood on (?) date, never showed fever or parasites.

Negative Case 3. Ibid.—Same source, injection and date. Subject showed neither fever nor parasites.

Negative Case 4. Ibid.—Same source, injection and date. Subject had slight transient rises of temperature two and six days after inoculation. No characteristic fever or parasites.

Note.—These four cases give strong reason for supposing that the sexual forms (crescents) are not in any way concerned in the reproduction of the parasites in the blood of the patient who contains them (section 20 (4)).

I am much indebted to Professor A. Celli for obtaining for me from Professor Giulio Galli an account of two interesting experiments performed by the latter, showing that malarial blood may be inoculated without result into subjects who are taking quinine.

Negative Case 5. G. Galli (?).—Source, benign tertian, many parasites; 0.5 c.c.m. of blood was injected subcutaneously into subject, a healthy woman who had been given 0.4 grams of "state" quinine daily for five days. The same dose was continued on 1st, 2nd, 5th, 6th, 7th, 12th, 13th, 14th day after inoculation, and then stopped. Subject remained in hospital for forty-two days after inoculation, but showed no sign of malarial infection.

Negative Case 6. Ibid.—Same source, amount of blood and method of inoculation. Subject, a healthy woman, was given 0.4 grams of quinine daily two days before inoculation, and six days after. She remained in hospital thirty-two days after inoculation, but showed no sign of malarial infection.

Remarks.—I have verified most of these cases from the original literature; but for a few of them the literature has not been obtainable. I have also omitted a few cases regarding which I can obtain no references.

* See also section 65 (2).
16. The Parasites develop in Certain Mosquitoes — I commenced the study of the mosquito-theory of malaria in Secunderabad, India, in April 1895. Numbers of mosquitoes of the genera Culex and Stomoxys were allowed to feed on patients whose blood contained the sexual forms of the parasites and were afterwards dissected in the hope of finding in them some developmental stage of the organisms. This investigation was continued without success until August 1897. Many hundreds of insects of various species (undetermined) of these genera were thoroughly searched, and many hundreds more were examined less completely — strong evidence in favour of the view that the parasites do not develop in these kinds of gnats.

On the 20th and 21st August 1897, I found the zygotes of the malignant parasites in two Anophelines (species undetermined) bred from the larvae and fed on a case of crescents. In September, I found them again under the same conditions in a mosquito of another species of Anopheline [December 1897 and February 1898].

About the same time MacCallum and Opie demonstrated the sexual nature of the crescents [1897].

On the 20th March 1898 I found the zygotes of one of the malaria parasites of birds, *P. dampsii* Grassi and Feletti 1890 (*Protozoa Labbe*), in *Culex fatigans*, and worked out the life-cycle of these parasites in the insects [1898]. It was however of fundamental importance to prove that the bodies found in the mosquitoes were really descended from the parasites found in the birds, and the following proofs were obtained —

1. The bodies in the mosquitoes contained the characteristic plasmodia (pigment) of the parasites in the birds.
2. Their growth and development were observed in detail in the insects.
3. Out of 249 mosquitoes fed on birds with no parasites or other parasites, not one was found to contain the
17. Experimental Mosquito Inoculations — We should begin by referring briefly to the early studies which showed that malaria cannot be communicated by marsh water. After the efforts of Salisbury in 1866, Balestra in 1869, Safford and Bartlett, Archer, Baccellini, Kiloh and Tonmaiati-Cudelli — well summarised in the paper of the last named (1879) — to incriminate various organisms as the cause of the disease, several Italians carried out good researches on the effect of drinking water. Celli failed in infecting six people by water brought from the Pontine Marshes (1886); and Proncoleone and Marino performed similar experiments. The work of Agostino Zen (1890) was very complete. He gave water from

1 Very roughly computed.
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The Pontine marshes and elsewhere to nine persons to drink in doses between 3 and 15 litres a day for five to twenty days each. To sixteen others he administered the water in the form of inhaled spray; and to five others by rectal injection. All the experiments were negative. Yet they should have succeeded if we suppose that the plasmodia live in such water and infect either by the respiratory or digestive passages—unless we assume that they died in the water during transit to Rome, where the experiments were conducted.

In 1895-1896 I made twenty-two experiments with a view to infecting healthy persons with drinking water in which mosquitoes had been allowed to lay their eggs and die (1896). The first case was, by a coincidence, attacked with fever; but as all the rest proved practically negative, I decided that no reliable evidence had been obtained one way or the other.

A. Bignami, in a paper discussing Manson's hypothesis (1896), stated that he had failed some time previously in causing infection by the bites of mosquitoes brought from malarious places. He believed with King that the insects bring the poison from the marsh, and I presume that his mosquitoes were therefore collected at random. This hypothesis was not in accordance with parasitological teaching.

The first correct experiments on mosquito-inoculation were performed by myself in August 1896. At that time I began to abandon part of Manson's hypothesis according to which the insects take the parasites from man and deposit them in water—I began to think that the insects take the parasites from man and also inoculate them into man. A number of several kinds of Culex and Stegomyia were therefore allowed to feed on various cases of malaria—one of which contained all the three species of parasites—and were then fed, after being kept for several days and on several occasions, upon Mr Appia, Assistant-Surgeon to my hospital in Bangalore, India. The results were entirely negative, the mosquitoes being of the
The first successful mosquito inoculations were those of birds. In 1898, four sparrows and a weaver-bird, which had frequently been found to contain no parasites and had been often used for controls in my laboratory for that reason, were bitten towards the end of June, on several nights in succession, by numbers of *Culex fatigans* heavily infected with *P. danielski*. On 9th July they were all found to contain “swarms of the parasites.” The experiment was next repeated on many more birds under proper conditions, with the following results:

1. Out of twenty-eight healthy sparrows twenty-two or 79% were infected in this manner.
2. One of the six sparrows that escaped the first experiments was infected on a second trial (the remainder died).
3. Out of two crows and four weaver-birds, free from *P. danielski*, one of the crows and all the others became infected.
4. Out of five sparrows, originally containing a very few *P. danielski*, four showed a much more copious infection after the experiments.

The experiments were quite decisive. At that time in Calcutta I found these parasites only in fifteen out of one hundred and eleven wild sparrows, and then only in small numbers in the blood. But, as I used large numbers of heavily-infected mosquitoes, the produced infections were extremely copious, as many as ten to sixty parasites being counted in each field of the microscope (oil-immersion lens). The incubation period was always four to seven days. This success was reported in England by telegram, and was published by Manson at the end of July 1898.

The following experiments have subsequently been performed on men.
Bignami succeeded in infecting a man by following my methods. A number of mosquitoes caught in infected houses at Maccarese were fed on a malaria-free inmate of the Santo Spirito Hospital, situated in a part of Rome where there is no malaria. They were fed on him nightly from 26th September to the end of October 1898, and belonged to Anopheles maculipennis, and two species of Culicines. The subject was attacked with slight fever on 31st October, and severe fever the next two days; quinine being given on 3rd November. In spite of careful search, the parasites (malignant) were not found until 3rd November, about forty hours after the first marked rise of temperature. Several relapses occurred later.

Anopheles maculipennis caught at Maccarese were fed from 13th November to 2nd December 1908, on a healthy subject in the same hospital. Fever commenced on 3rd December and continued daily until 9th; quinine on the 7th. Mild tertian parasites found on first day of fever. Parasites found also in the mosquitoes.

Note.—This fortunate experiment revealed that the tertian parasites also are carried by A. maculipennis. Gametids appeared on 6th December.

Case 3. Ibid.—Seven A. maculipennis caught in an infected house at Trieste were fed, each one once, on 10th, 11th, 13th, December 1898 on a subject in the same hospital. The protosporae were found in the salivary glands of two out of three of these insects examined. Subject attacked with fever on 29th December, the mild tertian parasites being found next day—two sets. Gametids on the 31st.

Case 4. Ibid.—Three A. maculipennis were fed on a case of crescents between 20th to 26th December 1898, were incubated at 30° C. for two days, and were then re-fed on a
healthy subject on 2nd and 5th January 1900. All three mosquitos were found to be infected, and two of them had sporozoites in their salivary glands. Subject was attacked with fever from 14th to 18th January. Quinine on 16th. Malignant parasites found on 15th and disappeared under quinine on 17th. No crescents found.

Case 5. P. Manson [1900].—Ten A. maculipennis were fed on a case of double benign tertian in Rome on 17th, 20th, 23rd August 1900, and bit P. Thorburn Manson in London on 29th and 31st August, and 2nd and 4th September. Also thirty-five of same species were fed on a simple benign tertian case in Rome on 6th and 7th September, and on the same healthy subject in London on 16th and 18th September. Fever began on 13th September, and continued on 14th, 15th, 16th and 17th. Benign tertian parasites found on 16th for the first time. Quinine on 17th. Relapse nine months later.

Case 6. Rees [October 1900].—A second subject, Mr. Warren, was bitten by the second batch of mosquitoes fed on previous subject at about the same time (not given). Fever commenced on 28th September after about fourteen days' incubation, and seemed to have continued for some time. Parasites in phagocytes on 30th. Benign tertian parasites on 2nd October and subsequently. Quinine on 3rd. Author says that this case showed fewer parasites than the previous one, as he was bitten by more mosquitoes.

Case 7. Fearnside [1901].—The following series of seven cases were obtained at Rajamundri, India, in 1900-1901. Unfortunately, the Anophelines were not identified, but the author states that only one species was used. Source, benign tertian, sporulated on 17th December, when the Anophelines were fed. Insects were re-fed on the author himself on 30th December and 1st and 8th January 1901. Tertian fever began on the 14th. Benign tertian parasites found on 18th. No quinine.
OBSERVATIONS AND EXPERIMENTS

Note.—Author had suffered from malignant malaria with haemoglobinuria in 1891, but that, apparently, did not affect the present experiment.

Case 8. Fearnside [1901]—Source the same, and Anophelines fed on same date. Subject (an Indian) bitten on 28th December. Tertian fever on 18th January. Benign tertian parasites on 21st.


Case 10. Ibid.—The same source. Anophelines infected 12th December and bit subject (Indian) on 20th. Tertian fever on 20th January, and tertian parasites on 25th. Apparently the same (one) mosquito used as in previous case.

Case 11. Ibid.—Source, double infection of malignant and of benign tertian. Anophelines infected 16th December, and bit subject (Indian) on 28th. Fever on 9th January, and malignant parasites on 11th; doubtful tertian parasites on 12th.

Case 12. Ibid.—Same source. Anophelines fed on same date and bit subject (Indian) on 28th December. Fever, 13th January. Malignant and benign tertian parasites on 14th.

Note.—Of two other cases experimented with by Fearnside one appears to have failed, and one to have contracted fever after fifteen days, the finding of the parasites not being noted. Author states that protaspares were found in all the Anopheles used.

Case 13. Buchanan [1903]—Experiments done at Nagpur, India. Source, malignant. Anophelines (species not given) fed 15th December 1901 to 8th January 1902, and bit subject...
171 MOSQUITO INOCULATIONS

10th to 17th January. Fever 27th January, and malignant parasites.


Case 15. Ibid.—Source, malignant. Anophelines fed 24th January to 4th February 1902, and bit subject 7th to 19th February. Fever 19th February, and malignant parasites.


Note.—Three attempts to infect from malignant sources failed. In two other cases, however, there was no fever after the mosquito inoculations, but crescents were found after twelve and eight days. These are not accepted here.

Case 17. Ibid.—Source, malignant. Anophelines fed 29th January to 11th February 1902, and bit subject 12th to 23rd February. Fever 1st March, and malignant parasites.

Case 18. Ibid.—Source, quartan. Anophelines (I species) fed 30th January to 11th February 1902; and bit subject from 18th to 27th February. Fever 25th, and malignant parasites (not those found in source).

Note.—Four other cases from quartan sources failed.

Anophelines not identified.


Case 20. Ibid.—Source, benign tertian. Anophelines fed 15th to 23rd January 1902, and bit subject 24th January to 10th February. Fever 15th February, and malignant parasites (not those found in source).
OBSERVATIONS AND EXPERIMENTS


Case 22. Ibid.—Source, benign tertian. Anopheles fed from 2nd to 14th February 1902, and bit subject 17th to 22nd February. Fever 1st March, and benign tertian parasite.

Note.—Five other attempts to infect from tertian source failed.

Case 23. Schuffner [1902].—Experiments in Sumatra with two species of Anophelines, apparently Cella kaudi Donitz, and a Mystomyia. Source, benign tertian. Anophelines fed 15th July (?) 1902, and bit subject, the author himself, on two days (1) 25th July. Fever, double tertian, 11th August, and benign tertian parasites.

Case 24. Ibid.—Same source, and Anophelines fed same date, and bit another subject on same date. Fever on same date, single tertian; and tertian parasites.

Case 25. Ibid.—Source, malignant. Infected Anophelines bit subject (Chinaman) on 20th, 21st August (?) 1902. Fever 5th September, and malignant parasites 7th.

Case 26. Jancsö [1905].—A long series of admirable experiments on the effect of temperature on the development of the parasites in Anopheline maculipennis; carried out at Kolozsvar, Hungary. Source, benign tertian. Six Anophiles fed 23rd September (9) 1904, and kept at 21°C for twenty-three days. Subject bitten 16th October, had fever on 15th day benign tertian parasites on 16th day.

Case 27. Ibid.—Source, malignant. Fifty-two Anophiles fed 26th October (9) 1904, kept at 30°C, and bit subject 3rd to 11th November. Fever 15th; malignant parasites 16th.

Case 28. Ibid.—Same source. Anophiles fed on 29th
October and kept at 30° C. Subject bitten 6th to 8th November by more than twelve. Fever 16th, and malignant parasites on 18th.


Case 30. Ibid.—Source, malignant. Anopholes fed 19th November and kept at 22-24° C. Subject bitten by seven on 20th. After ten days, fever and malignant parasites.

Case 31. Ibid.—Same source and mosquitoes. Subject bitten by one Anopholes on 29th January 1905. After fourteen days, crescents in blood.

Case 32. Ibid.—Source, malignant. Anopholes fed 15th November and kept at 20-24° C. Subject bitten by 11 on 16th December. After fourteen days, crescents in blood.

Case 33. Ibid.—Same source and mosquitoes. Subject bitten by one Anopholes on 6th December. After ten days, fever and malignant parasites.

Case 34. Ibid.—Source, malignant. Anopholes fed 29th September at 30° C. and afterwards kept at 20° C. Subject bitten 21st October by one Anopholes, strongly infected. Quinine 1-2 grams on 21st and 22nd. Fever and malignant parasites on 25th.

Case 35. Ibid.—Same source and mosquitoes. Subject bitten by two of these on 13th and 18th October. Fever 24th and crescents 25th.

All these cases have been verified by me in the original literature; but there are probably some other experiments which have been overlooked.1

1 See section 65 (55).
CHAPTER IV
THE PARASITIC INVASION IN MAN

18. The Onset of the Invasion.—It does not lie within the province of this book to give a full description of the pathology and symptoms of malarial fever—a subject which is dealt with, in many works. But before proceeding to our proper theme, we shall do well to examine a certain number of questions, especially some upon which little stress has been laid in the publications referred to. We should begin by attempting to obtain a clear picture of the onset and progress of the parasitic invasion in man.

Our first care should be to consider the number of organisms engaged in the invasion—a subject which has been much neglected. For example, in the eighty-six cases of successful experimental inoculations of men, I cannot find a single one in which correct estimates of the number of parasites in the source, the carrier, or the subject, have been even attempted. Certainly, these experiments prove the main theorem, that the parasites cause the disease; but they might easily have been used to obtain many valuable pathological data in addition. We are thus forced (at present) to rely largely upon calculation for our figures.

(1) The number of parasites in the mosquito.—The number of parasites which enter a mosquito when it feeds on a patient depends (a) on the amount of blood sucked up by it, and (b) on the number of parasites in that blood. The insects feed during variable periods—for a few seconds if disturbed, or perhaps
SECT. r8] ONSET OF INVASION

during the whole night upon a sleeping person. While feeding they void, every ten seconds or so, some of the fluid part of their meal; so that during a whole night they may possibly consume much more blood than one stomach-full. A mosquito fully gorged in this manner may (perhaps) consume several cubic millimetres of blood. It would be easy to settle this point by allowing a number of mosquitoes to feed during 1, 2, 3, 4 . . . minutes, and then killing and weighing them and their dejecta. For example, as R. Newstead has shown ("Reports Liv. Sch. Trop. Medicine, Liverpool," 1905, vol. xvii. p. 239, the tick Ornithodoros moubata weighs 0.027 grams before feeding and 0.260 grams after feeding. D. Thomson and myself find, in researches now being conducted in my clinic in Liverpool, that 6,000 crescents per c.mm. of blood is not an exceptionally high number. Supposing that only half of these are females, it is still very unlikely that so many could ever develop, after being fertilised, in one insect—a large or very large proportion probably perish from phagocytosis and other causes in the stomach contents. The largest number of developing zygotes found by me in one insect (C. fatigans gorged on blood with P. donovani) was 445. Ten of these mosquitoes fed all night on a bird with moderate parasites (1/100 haematid) were found to contain an average of 29 zygotes each; and ten of them fed on a bird with many parasites (1/50 haematids) contained an average of 100 zygotes each [May 1898]. But I do not know what proportion of the parasites in these birds were sexual forms. The number of zygotes found in Anophelines naturally fed on human blood does not very often, I think, exceed fifty—but this is probably due to the manner of feeding. The number of ingested sexual parasites which reach maturity and develop into spores depends (a) on the susceptibility of the insect, (b) on the temperature, and (c) possibly many other conditions. Janosi [1905] finds that the zygotes develop best at 24.3° C.

1 See reference to paper by S. T. Darling in section 60.
temperatures above and below these limits retarding the process
(A. maculipennis); and that they die if the mosquito is kept
constantly below 16°C after feeding. On the other hand, they
often continue to grow if the carrier is subjected merely to an
intermittent low temperature. Regarding the susceptibility of
various species of mosquitoes much work remains to be done.

(2) The number of protospores in the salivary glands—I may
have overlooked references, but do not know that the average
number of protospores in matured zygotes has ever been
exactly estimated. I should give the number (merely as an
impression) at about a thousand. Not all of these enter an
to entry into the salivary glands. Here, again, there seem to be
no exact counts. I fancy that more than 10,000 of them will
seldom be found in the glands of a single Anopheline, while
often there may perhaps be only a few hundreds at a time
(subject to correction).

(3) How many protosporcs enter the human blood?—This
must depend (a) upon the number of spores in the biting
insect’s salivary gland, and (b) upon the number of times it is
allowed to bite its victim. I think that mosquitoes inject their
poison before commencing to suck. If this is the case, any
insect which bites a person several times (as, for instance, when
he is asleep) is likely to inoculate many more protospores than
one which succeeds in biting only once. In the former case
several thousand spores may perhaps be introduced; in the
latter case perhaps only a few.

But not all of the spores which have entered are likely to
live. Probably many perish by falling outside the blood stream
or by becoming a prey to phagocytes.

(4) Further development of the protosporcs.—F. Schaudinn
observed that if protospores are taken from a mosquito’s
salivary gland and are mixed with blood under the microscope,
many of them may actually be watched entering the haematids,
where they become the young intracorporeal parasites familiar
to students. These now begin to grow and to develop a second
generation of spores, which should be called deuterospores. The latter attack fresh haematids, within which they grow, and develop a third generation of spores, which we may call tritospores; and so on indefinitely.

(5) The number of spores produced by each species of parasite—The parasites of malaria are described in detail in the textbooks. Since the time of Golgi, all observers admit that they belong to three types at least, each of which differs microscopically, and markedly so, from the others. I assume, for the sufficient reasons frequently given, that these three types are three different species. The number of spores produced by each species is variable, and different authors give different figures (probably the number has never been accurately estimated). I adopt the following names and figures for the present—

*Plasmodium malariae* Laveran, 1881. The Quartan Parasite; produces say 6-12 spores every three days.
*Plasmodium vivax* Grassi and Feletti, 1890. The Benign Tertian Parasite; produces say 15-20 spores every two days.
*Plasmodium falciparum* Welch, 1897. The Malignant Parasite; produces say 6-20 or more spores every two days.

Some authors consider that there are two if not three varieties (or 3 species) of malignant parasites. I am inclined to agree with them, but have not yet satisfied myself sufficiently on the point to admit it in my classification.

(6) The onset of the invasion—Let us suppose that a mosquito has inoculated several thousand protospores, but that only one thousand of these have succeeded in entering the haematids. After two or three days, according to the species of parasite, each will produce a variable number of deuterospores. But, probably, not all of these will succeed in infecting fresh haematids; many may be devoured by phagocytes, or be destroyed by other agencies, while passing from one haematid to another. And the same thing is likely to happen with every successive generation of spores. Hence only a proportion of
the spores actually produced are likely to enter fresh corpuscles.

Suppose that 1,000 protospores of *P. vivax* have entered haematids, and that, on the average, only 10 out of the 15-20 spores actually produced in the successive generations succeed in entering fresh haematids. The parasites should then multiply as follows:

<table>
<thead>
<tr>
<th>No. of days</th>
<th>No. of parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,000</td>
</tr>
<tr>
<td>2</td>
<td>10,000</td>
</tr>
<tr>
<td>4</td>
<td>100,000</td>
</tr>
<tr>
<td>6</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

and so on.

In the case of *P. malarias* the multiplication should be slower, if the number of spores given above is correct. But in that of *P. falciparum* the data are too uncertain for calculation.

(2) The number of haematids in an average man.—According to accepted standards we have:

- A c.mm. of blood contains 3,000,000 haematids.
- The specific gravity of blood (male) is about 1.0573.
- The total amount of blood weighs about 4.9% of the total weight of the body.

From these data we calculate that 3,000,000 c.mm. of blood weigh 3.17 kilograms, and will be contained in a man weighing 64.74 kilograms (142 lbs. English, or about 10 stone), and that these 3,000,000 c.mm will contain 15,000,000,000 haematids.

This may then be taken as the normal number of haematids in an average healthy man of about 64 kilograms, or 10 stone, in weight. The reader should endeavor to form some tangible idea of this enormous number. If he were to try to count it at the rate of 100 a minute day and night without cessation, he would have to spend 285,000 years over the task!

The ratio of blood to body weight was formerly estimated at about 1/13, but the estimate has recently been reduced in consequence of better methods of measurement.
(8). The lowest number of parasites required to produce the first illness.—We can scarcely imagine that one protospore, or even many thousands of these minute bodies, can produce any marked symptoms in the patient; and, in fact, we learn from the fundamental experiments of the period no symptoms appear for some days after the moment of inoculation—this period being commonly called the incubation period. But as the parasites increase at every generation, a time must come when the number of them will suffice to cause illness. Can we determine this number? No serious attempt has yet been made to do so, or, indeed, to find any exact correlation between the number of parasites and the amount of sickness. There are many difficulties in the way. It is not always easy to estimate the number of parasites, and still less to know when precisely the illness commences. In most of the experimental inoculations, some illness, or even sharp fever, has occurred before any parasites have been found by the microscope. On the other hand, Elting has been able to find the parasites in some of his cases before the onset of the fever. The question is probably determined partly by the skill and patience of the observer, partly by the susceptibility of the patient, and partly by the "virulence" of the parasites. A laborious search may reveal the parasites when they are comparatively few in number; and on the other hand, a patient who has never been previously infected will probably begin to suffer earlier during the course of the invasion than one who is partially "immune." But for a broad general rule we may, I think, accept the principle (pending more exact researches) that if we cannot find the parasites after careful search, their number is not usually sufficient to produce fever. Hence I calculate that they will not generally be numerous enough to cause illness unless there is at least one parasite to 100,000 hematids; that is, 50 parasites in 1 c.m. of blood; or 150,000,000 in a man of 10 stone (64 kilograms) in weight.

(9). The time required to examine blood microscopically.—It
is very necessary to have clear ideas upon this point. Suppose that the diameter of a "field" seen by an oil-immersion Objective and a No. 2 Ocular measures 0.165 mm., or nearly 1/6th of a millimetre. Then by moving the specimen across this field of vision, searching it as we move it, we shall cover, after traversing sixty times the diameter, a strip nearly 10 centimetre long and 0.0165 cm. broad. Examining strip after strip in the same way, when we have examined sixty strips we shall have covered nearly one square centimetre of area.

The time required for this will depend upon the care with which we must examine the successive fields as they pass under the eye. If we can snatch at the rate of twenty fields a minute, we can search a whole strip in three minutes; and a whole square centimetre in three hours. If the object is large and easily visible we shall be able to move the specimen faster than this; if it is small and delicate, the observer must be fairly expert to search so quickly.

Now suppose that we must examine a thin film of liquid blood spread under a coverglass. If the average depth of the film is only 0.00025 mm. (0.33 or about 1/3 the diameter of haematid), then 1 c.mm. of the blood will be spread out under 4 sq. cm. of area—that is, over the whole area occupied by a square coverglass of 2 cm. side. To do this will require twelve hours' continuous work. If the average depth of the film is 0.0005 the c.mm. of blood will cover a space of 3 sq. cm., requiring nine hours' search; but in this case we shall be more liable to overlook small objects, though we shall more easily find large ones.

With an average depth of 0.0005, 1 sq. cm. of film will normally contain 1,250,000 haematids. One-sixtieth of this, that is, one strip as defined above, will contain 20,833 haematids; so that, if we are fairly expert, we should be able to search 6,944 or say 7,000 haematids a minute. With an average depth of 0.00025, 1 sq. cm. of film will contain 1,666,666 haematids.
TIME REQUIRED FOR SEARCH

haematids which can be searched at the rate of 3,159 haematids a minute. In the former case a single circular field of the microscope, 165\(a\) in diameter (area 0.09 sq. mm.), will contain an average of about 261 haematids. In the latter case it will contain about 343 haematids on the average. There are, of course, more than 3,000 squares of 165\(a\) side in a square centimetre: and therefore four and three times this number of squares must be examined to search 1 c.mm. of blood in films of 2.5\(a\) and 3.3\(a\) in depth respectively. If we could examine the squares at a rate so fast as one a second, three to four hours would still be required to search 1 c.mm. completely. To search the whole of the 3,000,000 c.mm. of blood contained in a man of about 10 stone in weight would therefore take, at the quickest rate, more than 1,027 years.

I have just estimated roughly that the parasites will probably be numerous enough to cause fever if they number 100,000 haematids. If it requires twelve hours to search 1 c.mm. of blood containing 5,000,000 haematids, 100,000 haematids can be searched in a little less than fifteen minutes; so that if the parasites are so few as this we can expect to find them at the rate of about one every quarter of an hour. But chance intervenes here: if we are lucky we may find the first parasite almost at once: if we are unlucky we may have to search several hundreds of thousands of haematids before finding an infected one. There is always the danger of overlooking a plasmodium even when it should have been seen.

In a dry stained film the blood is spread out over a wider area, so that there are only about 150-200 haematids in a circular field of 165\(a\). I think therefore that the larger pigmented parasites are less quickly found in such than in liquid films: but on the other hand, the smaller plasmodia, being characteristically coloured, are detected with much greater certainty—as Marchoux showed [1897]. On the whole, I think that the two methods are about equal in diagnostic value. •

In my “thick-film” process (1903), 1 c.mm. of blood
occupies only about 1/5th of a sq. cm. of area, or less, so that there should be twenty to thirty times more haematids and parasites per field. But the latter require more skill for detection (section 65).

Such calculations demonstrate the absurdity of supposing that there are no plasmodia present in a person because we fail in finding one after a few minutes' search. As a matter of fact, even if as many as 150,000,000 plasmodia are present in an average man, the chances are that ten to fifteen minutes' search will be required for each plasmodium found; while if we are careless or unfortunate we may have to look much longer.

The period of incubation.—To resume our study of the invasion—we saw in subsection 6 that, in the case of P. vivax, 1,000 protospores should produce 100,000,000 parasites in ten days and 1,000,000,000 in twelve days. The former number would probably be insufficient to produce fever in the patient, and the latter would be more than sufficient. Hence the illness would probably begin on the twelfth day after inoculation.

It is usually thought that the incubation period must depend exactly upon the number of organisms injected either by the mosquito or by the experimenter; but this is not always correct. The proliferation of P. vivax at the rate of ten spores at each generation every second day, starting with various initial numbers, should be as follows:

<table>
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<td>1,000,000</td>
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<td>190,000</td>
<td>1,900,000</td>
<td>19,000,000</td>
</tr>
</tbody>
</table>

Thus, starting with 1,000 protospores, the number of parasites required to produce fever, namely 150,000,000, will not be attained until the twelfth day. Starting with 2,000 protospores, this number will, it is true, be attained on the
tenth day, two days earlier; but after this point we shall have to increase the number of protospores originally injected up to $15\times 10^3$ before we can reduce the incubation period by another two days. In other words, if we estimate correctly, 2,000 protospores should give as long an incubation period as $14\times 10^3$ protospores, or seven times as many, would give.

That is, it makes little difference to the patient whether he is bitten by one or by seven mosquitoes, each of which injects 2,000 protospores. It is possible that even two or three protospores, if they survive, would set up infection. I have assumed that $F. vissus$ increases tenfold at every generation, but this is a mere guess. The following table gives the first seven powers of some natural numbers and the proliferation of a single placmodium according to various rates, from fivefold to twofold. The party-line shows where the numbers, if multiplied by 1,000, would reach the fever-point.

<table>
<thead>
<tr>
<th>Powers of Natural Numbers</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>2</td>
<td>4</td>
<td>8</td>
<td>16</td>
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<td>6</td>
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<td>7</td>
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<tr>
<td>9</td>
<td>1</td>
<td>9</td>
<td>81</td>
<td>729</td>
<td>6561</td>
<td>59049</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>10</td>
<td>100</td>
<td>1000</td>
<td>10000</td>
<td>100000</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>11</td>
<td>121</td>
<td>1331</td>
<td>14641</td>
<td>161051</td>
</tr>
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<td>13</td>
<td>1</td>
<td>13</td>
<td>169</td>
<td>2197</td>
<td>28561</td>
<td>371293</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>15</td>
<td>225</td>
<td>3375</td>
<td>50625</td>
<td>759375</td>
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<tr>
<td>20</td>
<td>1</td>
<td>20</td>
<td>400</td>
<td>8000</td>
<td>160000</td>
<td>3200000</td>
</tr>
</tbody>
</table>

This table may prove useful for estimating the average rate of increase of the various parasites, exact experiments upon which are much needed. I think it possible that more spores may be produced early in the infection than later; and also that there is likely to be a much smaller mortality among the spores at first than there is later, when the germicidal powers of the host become (hypothetically) stronger.
The following table gives the incubation periods actually found in the fundamental inoculation experiments described in sections 14 and 16, omitting the doubtful results. The cases are numbered as in those sections.

### 1. P. MALARIAE: Blood Inoculations

<table>
<thead>
<tr>
<th>Case</th>
<th>10 13 14 16 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of blood (c.c.)</td>
<td>5 7 7 5 4</td>
</tr>
<tr>
<td>How injected</td>
<td>cut. ven. cut. cut. cut.</td>
</tr>
<tr>
<td>Incubation (days)</td>
<td>12 13 17 12 11</td>
</tr>
</tbody>
</table>

### 2. P. VIVAX: Blood Inoculations

<table>
<thead>
<tr>
<th>Case</th>
<th>29 30 35 36 37</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of blood</td>
<td>2 3 2 4 4</td>
</tr>
<tr>
<td>How injected</td>
<td>cut. cut. cut. cut. cut.</td>
</tr>
<tr>
<td>Incubation</td>
<td>16 11 25 25 20</td>
</tr>
</tbody>
</table>

(No mosquito inoculations.)

### 3. P. VIVAX: Mosquito Inoculations

<table>
<thead>
<tr>
<th>Case</th>
<th>9 12 13 20 31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of blood (c.c.)</td>
<td>5 6 7 5 5</td>
</tr>
<tr>
<td>How injected</td>
<td>cut. ven. ven. ven. ven.</td>
</tr>
<tr>
<td>Incubation</td>
<td>11 11 12 12 10 10</td>
</tr>
</tbody>
</table>

### 4. P. FALCIPARUM: Blood Inoculations

<table>
<thead>
<tr>
<th>Case</th>
<th>10 11 24 25 27</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of mosquitoes</td>
<td>3 6 6 6 6</td>
</tr>
<tr>
<td>Incubation</td>
<td>21 15 15 17 17 15</td>
</tr>
</tbody>
</table>

### 5. P. FALCIPARUM: Mosquito Inoculations

<table>
<thead>
<tr>
<th>Case</th>
<th>15 17 22 25 27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of blood</td>
<td>15 15 0.75 0.25 2 5 0.75</td>
</tr>
<tr>
<td>How injected</td>
<td>cut. cut. cut. cut. cut.</td>
</tr>
<tr>
<td>Incubation</td>
<td>15 15 12 3 4 5</td>
</tr>
</tbody>
</table>
### P. FALCIPARUM: Blood Inoculations

<table>
<thead>
<tr>
<th>Case</th>
<th>28</th>
<th>31</th>
<th>33</th>
<th>39</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of blood</td>
<td>0.2</td>
<td>1.5</td>
<td>1.5</td>
<td>0.2</td>
</tr>
<tr>
<td>How injected</td>
<td>cut.</td>
<td>cut.</td>
<td>cut.</td>
<td>cut.</td>
</tr>
<tr>
<td>Incubation</td>
<td>10</td>
<td>30</td>
<td>17</td>
<td>2.5</td>
</tr>
<tr>
<td>Case</td>
<td>40</td>
<td>43</td>
<td>44</td>
<td>46</td>
</tr>
<tr>
<td>Quantity of blood</td>
<td>1.5</td>
<td>1.5</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>How injected</td>
<td>cut.</td>
<td>ven.</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Incubation</td>
<td>17</td>
<td>7.5</td>
<td>4</td>
<td>?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case</th>
<th>26</th>
<th>30</th>
<th>31</th>
<th>33</th>
<th>34</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of mosquitos</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>14</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Incubation</td>
<td>15</td>
<td>14</td>
<td>11</td>
<td>11</td>
<td>21</td>
<td>11</td>
</tr>
</tbody>
</table>

From these figures we collect the following extremes and averages for the incubation period in days per case.

<table>
<thead>
<tr>
<th></th>
<th>Lowest</th>
<th>Average</th>
<th>Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartan, blood inoculation</td>
<td>11</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Tertian, blood inoculation</td>
<td>3</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>P. falciparum, blood inoculation</td>
<td>15</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>Malaria, mosquito inoculation</td>
<td>15</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>P. falciparum, mosquito inoculation</td>
<td>6</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

As we might expect, P. malariae gives the highest average incubation period, P. falciparum gives the lowest, and the mosquito inoculations have distinctly longer periods than the blood inoculations.

The short periods given by some of the blood inoculations may be easily explained. When discoverable in ordinary thin-film preparations, the parasites may number anything from 50 per c.mm., or less, to 200,000 per c.mm., or more. In the latter case there will be 200,000,000 parasites per c.mm., so that if 1 c.mm. or more of such blood is injected, the subject should receive enough parasites to produce fever at once.
hypothesis in a non-immune person; and this has almost occurred in some of the cases. But, besides the number of parasites contained in the inoculated blood, there is another question requiring consideration; that is, whether many of them are not killed in the syringe. In spite of the experiments of Belo and Sucharoff (18-21 and 24), I think that this is possible, or even likely. The experiments of Celli and Santori (33-45), in which various sera were mixed with the inoculated blood, generally show long incubation periods, probably due to such destruction of the parasites. It is unfortunate that the inoculated parasites have not been counted in a single one of these experiments.

We need not refer here to incubation periods determined by observation of natural infections.

19. The Further Progress of the Invasion.—We now endeavor to trace the progress of the invasion after the commencement of the fever.

1. Increase of the parasites.—In assuming that about fifty plasmodia per c.mm. are required to produce the first illness, we must remember that this applies only to a single set of parasites. If the patient contains several sets, each sporulating on different days, the total number of plasmodia should, by hypothesis, be several times larger. Moreover, it does not follow, if fifty plasmodia per c.mm. are sufficient to produce the first attack, that they will suffice to cause subsequent ones after the patient has become (hypothetically) habituated to their poison. Lastly, the various species may vary in "virulence."

As I have said, this number, which may be called the "gross limit," is merely a rough estimate of mine. Long researches are required to obtain a more exact figure from observation, but it may be useful to give a few of the first counts made by D. Thomson and myself in cases in Liverpool, that is, not in fresh infections;—
In the malignant cases, the young forms, being merely the offspring of the mature parasites which caused the corresponding forms and which were at the time in the inner organs, do not give the number of the parent forms; but we may form a rough estimate of the latter by dividing the number of young forms by ten. The quartan case (triple) gives some justification for the figure which I have tentatively selected as the pyrogenous limit (addendum 1).

From this point, to judge from the experimental inoculations and also from general clinical experience, the progress of an untreated case is generally that the parasites continue to increase in numbers till they may reach the figure of several hundred thousands per c.mm.

No accurate computations of the increase of the parasites seem to have been attempted even where their numbers are large enough for easy enumeration. If they increase by 10 at each generation, they should multiply from 50 to 5,000 in four days for tertian parasites, but there is reason to suppose that the increase now begins to be considerably checked.

(a) The maximum number of parasites—I do not consider that 200,000 young malignant parasites per c.mm. is exceptionally high. In Mauritius we found in a fatal case 12,000 of the haematsids infected. Several authors record 50,000, and Rogers 50

Here P. stands for the Pyretic State which I propose for pathological work. It is nearly the Congiunct Value between 37° and 41° divided into 100 parts. Thus:

- 37° P. = 37° C. = 98° F. = 30° R. = normal human blood temperature
- 41° P. = 41° C. = 105° F. = 39° R. = high fever.
THE PARASITIC INVASION IN MAN [SECT.

[1908, p. 222] mentions a fatal case "with more parasites than corpuscles." Three or four parasites are frequently found in one haematid. Similar copious infections are the rule in genus *Macropneumon (Haemoproteus)* of birds.

There are innumerable references to this part of the subject in the literature, but none of them are exact. Many authors give the proportion of their cases in which they have detected the plasmodia in a single thin-film specimen—that is, I suppose, in numbers over about 50 per c.mm. Rogers states that out of his successful cases they were detected in a minute or two in 78% and in over five minutes in 10%; but he failed to find any parasites in 10-20% of undoubted malaria cases. Other observers have had still more failures. In Liverpool we nearly always succeed if fever is present, but the blood is generally distributed to a class. It is obviously a question not only of the number of parasites, but of skill; and I should add that not all of those who write on the subject are as expert as may be imagined.

According to the classical theorem of Marchiafava, Celli and Bignami, the sporids of *P. falciparum* tend to retire to the inner organs after reaching a certain size. I remember a case where I undertook to demonstrate the plasmodia to a sceptic, and found for the purpose a case swarming with young malignant parasites. A few hours later, however, when the sceptic saw the case, they had all vanished! Nevertheless, I think that this theorem requires to be better verified by strict numerical work, as it is possible that much of this supposed disappearance from the peripheral circulation is due to the death of the organisms (addendum 1).

(3) Limitation of the invasion.—Clearly, if the parasites can continue to multiply for ever at the original rate, every untreated case would infallibly die. We are therefore obliged to admit that something happens to check the invasion. The subject belongs to the pathology of malaria, but we should note the following points.
The arrest of the invasion may be due to one or both of two causes. Either the parasites themselves begin to lose their power of reproduction, or else they or the body produce something which opposes them. I doubt the former hypothesis, because the same number of spores appear still to be formed; because the parasites do continue to reproduce in smaller numbers for months, or even years; and because in some cases they actually do continue multiplying until they kill the patient. Whether they are destroyed by their own toxins, or by some germicidal substance produced by the host, is a question which deserves much more attention than it has received. The idea that they are destroyed solely by the phagocytes is no longer generally accepted.

Whatever it is, the germicidal substance appears usually to increase in power with the number of the parasites, and therefore to check the invasion at its height. On the other hand, the failure of many inoculation experiments suggests that some persons possess such a substance from the first—unless the failures have been due to some unseen error. Out of six birds which escaped infection in my mosquito inoculations, only one (the only survivor) was infected on a second trial; and the same thing happened in some of the human experiments.

The literature contains many references to the sudden disappearance of a whole generation of plasmodia—not in consequence of quinine, but frequently following rest in bed, good food or shelter from heat. In the quartan case mentioned in subsection (1), a large brood followed the sporulation of 24th January, but of these, without quinine, only about 36 per cent. reached maturity three days later. Many observers describe the appearance of death-loss or change of staining capacity, and so on, among the parasites on such occasions.

(4) The illness is due to a toxin—This point also belongs to the pathological side of the subject. Omitting reference to the older hypotheses, it is now almost certain that the patient's fever is connected with the discharge of some toxic substance...
from each mature sporid at the moment when its spores are scattered in the serum. Some of the older inoculation experiments made with blood taken from a source in the state of rigor—that is, at the moment when the sporids are breaking up—were followed by an immediate slight reaction, suggesting that that blood contained a toxin as well as parasites. These results are, however, scarcely definite enough to prove the point, especially as the inoculation of healthy blood is sometimes followed by such a reaction. But the following excellent experiments of Rosenau, Parker, Francis and Beyer [1904] were much more decisive.

Case 1. At Vera Cruz, Mexico, at noon on 27th October 1903, 100 c.cm. of blood were drawn from F. Martinez, suffering from a declining paroxysm of P. falciparum; temperature 38.4° C. (=122°F.); parasites, young sporids and also gametids. The serum of this blood was separated, diluted with an equal part of salt solution, passed through a Chamberland B filter (tested), and injected (20 c.cm.) into J. Ojeda, and (equiv.) into L. Peredo. Neither subject showed any symptoms.

Case 2. At the same place, at 12:30 on 27th November 1903, A. Mendez was suffering from a severe benign tertian rigor (double infection); temperature 39.2° C. (102.6°F.), rising to 40.2° C. (104.4°F.). At that moment 125 c.cm. of his blood were drawn and defibrinated. To 25 c.cm. the same quantity of salt solution was added, and the mixture was passed through the same filter. The filtrate had no figured elements, but showed a red tinge, and 9 c.cm. of it were injected at 1:40 P.M. into the right basilic vein of L. Peredo. Thirty-five minutes later the subject began having chilly sensations and headaches, and presently went to bed covering himself with his blanket (2:25 P.M.). Five minutes later (2:30) he was having a violent chill, his teeth chattering so that we could not trust the thermometer in his mouth. Patient was pale and vomited. Chill lasted to 3:15 P.M.; vomited again at 3:30; fever rose
rapidly to 38.7° C. (17° F.) at 4 P.M., nearly normal at 10.30 P.M.

Authors put the duration of the paroxysm at about eight hours.

**Case 3.** At same place and date, at 2 P.M., 2 c.c.m. of the
same blood of A. Mendez, mixed with an equal volume of salt
solutions, but unfiltered, were injected intravenously into J.
Ojeira. Subject "reacted within an hour, with a slight rise
of temperature and nausea, and four days afterwards developed
a typical malarial paroxysm, with many tertian parasites in
his peripheral blood." Typical fever (double infections)
with a few parasites at 7 a.m. on 10th November. (Case 31 of
section 14.) In this case the preliminary rise of temperature,
which began within an hour after injection, reached 37.9° C.
(9° F.) and lasted five hours.

Thus, both the subjects inoculated with the blood of Mendez
taken during rigor had attacks of fever similar to that of the
source; but the first subject inoculated with filtered blood did
not become infected, while the second subject inoculated with
unfiltered blood became infected with the same parasites as in
the source.

Unfortunately, no estimate is given of the number of parasites
in the inoculated blood. The infection of Mendez was, however,
said to be "heavy"—let us suppose 10,000 parasites per c.mm.
We may thus calculate—

The toxin of 45,000,000 benign tertian parasites in 4.5 c.c.m.
of blood caused eight hours' fever, reaching to 38.7° C. (17° F.)
in Peredo.

The toxin of 20,000,000 of the same parasites in 2 c.c.m. of
blood caused five hours' fever, reaching to 37.9° C. (9° F.) in Ojeira.

The corresponding ratios, namely, 45:20, 8.5, 17 9 (taking
0° F., as the normal temperature), are not dissimilar. The pyr-
genous limit here suggested is lower than my arbitrary figure
of 100,000,000; and I may have underestimated the infection
of Mendez, and the weights of the subjects are not recorded.
The corresponding paroxysm of Mendez himself rose to 40° C. and lasted five hours; but his was an old case, and cannot be compared with the others.

We do not know the nature of the toxins, but I have always thought it likely to be some soluble constituent of the plasmodia. It is generally supposed that the various species of plasmodia produce toxins of different strength (or virulence); but we should await better proof of this.

(5) Antitoxins.—Just as the body certainly produces some germicidal property capable of limiting the number of the parasites, so it must certainly produce some antitoxic property capable of destroying, or at least eliminating, their poison. We do not know its nature, but infer for the following reasons that its power increases with time:

1. From the time of the ancients it has been observed that malarial fever begins with remittent fever, due to the overlapping of the paroxysms, and ends with intermittent fever, due to the shortening and separation of the paroxysms. This shortening of each attack of fever is not always accompanied by a decrease in the number of parasites, and must therefore be due to something which reduces their effect on the body.

2. Old cases, especially children, often scarcely feel the paroxysm, although considerable fever may be present.

I have observed in many untreated cases that the number of parasites continues to increase, although each attack of fever tends to become more and more mild. This suggests that the antitoxic power of the blood tends to be developed sooner than the germicidal power.

20. The Decline of the Invasion.—(1). The period of regular paroxysms.—It is not easy to find untreated cases for study, but from such as I have been able to examine or to read about,
I infer (subject to correction by more exact numerical methods) that the following course of events occurs:

After reaching a figure of say 500 or 500 per c.mm. the parasites tend to increase more slowly owing to the increasing germicidal power of the blood. That is, while each sporid still produces the same number of spores, a greater and greater number of the young sporids are killed; so that the invasion tends to reach a limit of something like 1,000 to 10,000 mature sporids at every generation. But this limit may not be reached perhaps for some weeks.

In the meantime the increasing antitoxic power of the blood tends to shorten each paroxysm more and more; the fever, at first remittent, breaks up into a series of intermittent attacks. Thus, though at each paroxysm the total number of parasites may be slightly increased as that number approaches the highest limit, yet the parallel increase of the antitoxic power annuls the effect of the parasitic increase, so that the patient now often suffers from a long series of paroxysms of almost equal intensity, which give the typical classical picture of a malarial fever.

This period may last, I think, for some weeks, but of course the process may be subject to modification. Thus, food and rest may help the patient, while in some cases death may occur in spite of quinine from an unlimited propagation of the parasites.

Fortunately, however, the period ends abruptly in most cases even without quinine. The paroxysms become very mild, and then, suddenly, the sporids undergo an immense fall in numbers; and this stage of the disease ends.

The collateral incidents and symptoms are minutely described in pathological books, and it is necessary here to refer only to some important points.

According to the elementary law of Golgi, a patient may contain, not only one set of parasites sporulating every second, or every third day (as the case may be), but two or three sets sporulating on different days. He may also contain sets of
parasites of different species. The rule generally accepted is that each set of parasites continues its own evolution independently of other sets which may be present. But much more precise work requires to be done on this point, and on the following:

(a) The exact increase of severity, if any, of a paroxysm due to the simultaneous sporulation of two sets of parasites of different species on the same day.

(b) Does one set of parasites affect the body-reactions against another set of the same or of a different species?

(c) Do different sets of the same species tend to coalesce?

(d) Explanation of the (apparent) extinction of one set long before that of another.

The presence of different sets may obviously be ascribed to inoculation of the patient on different dates. This matter has already been touched upon, but not exhaustively, in some of the inoculation experiments, especially in those of De Mattei, Elting and Jancsi.

Besides fever, the parasites produce alopecia. This has often been measured absolutely, but never exactly in correlation with the number of parasites. It is supposed that the toxin of the plasmodia destroys many of the hematids which are not mechanically broken up by the parasites themselves. More exact researches are also required regarding the absolute and relative haematologic variations in correlation with the number of plasmodia.

The different species produce paroxysms of somewhat different type and intensity. Many authors quote figures, but without correlation with the number of parasites. Thayer and Hewetson [1895] give 11 hours as the average duration of the single benign tertian paroxysm, about ten hours as that of quartan paroxysms, and twenty to twenty-one hours as that of the malignant paroxysms. The meaning of the malignant parasites in the inner organs, and many other details, are
pathological matters. The enlargement of the spleen and liver will be dealt with in section 22.

(i). The appearance of sexual forms.—With the quartan and benign tertian parasites, these forms begin to be seen very early after the plasmodia become numerous enough to be found at all. It is very doubtful whether they are or are not produced in broods at any given moment during the course of the invasion or during the development of a single generation; and still more doubtful how long a single gametid can live in the blood of the patient. The opinions of many writers may be quoted, but, unfortunately, they are only opinions. Schaudinn's case will be referred to presently. The malignant gametids are much more easy to study. They begin to appear about a week after the onset of the fever and may remain circulating in the blood for several weeks. We do not know what determines their appearance, but the asexual forms and the fever frequently vanish when they appear (which may often be due to the fact that quinine influences the sporids more than it affects the crescents). In untreated cases, however, we may often find both forms together for many days, though the sporids are apt to be scanty. In such cases there may be slight oscillations of temperature, which some writers have attributed to the crescents. Often, also, the sporids may be still present in large numbers though they are too few to be detected. In infected sailors in Liverpool we often find crescents with great certainty, unless the earlier infection is cut short with quinine. But many writers complain that in certain localities they cannot find them as frequently as might be expected, and I have had the same experience in India and West Africa. To explain such cases I have surmised that the production of sexual forms may be largely influenced by season—that they may be produced abundantly for a few weeks, but only at that time of year when the local carrying Anopheles lines are most abundant. Caccini [1902] says that several observers have noted the absence of crescents when the new
malaria season is imminent, and that he himself has never found crescents in Italy from April to June. For another example, I found very few crescents at the foot of the Darjeeling mountains in 1868 at a place where they had been frequently seen by another observer a few months earlier. But this is a mere conjecture, and one which requires long study for verification; and it scarcely explains why sailors in Liverpool have crescents so regularly. The early use of quinine—to which sailors are not addicted—may also explain the paucity of crescents in many cases. Lastly, it is possible that the sexual forms are produced only during the earlier stages of an infection—that in an old infection, when, so to speak, parasites become worn out, they no longer produce sexual forms, just as the eldest broods of human cells fail to produce them. In my experience crescents are common during the first few months of an infection, but comparatively rare at later stages. Failure to find "flagellated forms" (spermatophoria) must be generally due to faulty techniques.

3. The period of rallies and relapses.—We have seen that the period of regularly repeated paroxysms generally ends after a few weeks, even without treatment, in a great decline in the number of sporids. The gametids, especially the crescents, may still remain numerous, but the asexual forms which cause the illness diminish so much that they fall below the pyrogenous limit and cannot easily be found.

The patient now improves in health. His paroxysms cease, his haemoglobin increases, his spleen diminishes, and he begins to gain flesh again. I call this the rally. From this point two things may happen. The patient may recover completely, or—without reinfection—he may suddenly suffer from a relapse.

In the relapse all the old symptoms of the period of regular paroxysms, sometimes less in intensity and sometimes worse, recur. The fever may recommence with the remittent form, and may then, as before, become intermittent. The
anaemia and the splenomegaly—not yet completely recovered from since the first attack—will again increase, and to a greater degree than at first. Large numbers of sporids will again be found in the blood, and may be followed as before by crops of gametids. Finally, in most cases, even when untreated, recovery, accompanied by a great decrease of sporids, will occur again. This is followed by another rally, which in its turn may be followed by another relapse—and so on, indefinitely, for months or perhaps years.

Such, in my opinion, is the normal course of malaria, whether untreated or badly treated. But as the former kind of case can scarcely ever be observed, my opinion is based, not upon continuous observation of many cases, but upon correlation of different periods in different cases. I think, however, that most students of tropical malaria share that opinion.

During the whole of this period the emaciation, anaemia, splenomegaly and secondary symptoms tend to increase with each relapse and to diminish with each rally. But the increase seems at first to be generally greater than the decrease, though by a diminishing increment. Thus, after some months the patient tends to reach a condition in which these symptoms arrive at something like a fixed limit—considerable emaciation, anaemia, splenomegaly, oedema, dyspepsia, etc. This condition is well known as that of chronic malaria, and is only too frequently seen in malarious places, especially among children.

In most cases, especially in children, after the fixed limit has been reached a general improvement sets in. After all, the disease is essentially a benign one. Each relapse now affects the patient less and less, and the secondary symptoms begin to decrease more with each rally than they increase with each relapse. After an unknown average duration, complete recovery certainly occurs in the large majority of cases, without any serious treatment. Such cases are said to have become partially immune.
On the other hand, death occurs in many as the result of "pernicious paroxysms," intercurrent affections such as dysentery and pneumonias, or general weakness caused by poverty caused by inability to work.

Of course this picture—or rather sketch—is modified by many conditions. Patients who have already become partially immune during childhood or after many attacks, suffer much less on re-infection; and good food and change of climate benefit the case, while complications such as dysentery, sprue and ankylostomiasis, have the opposite effect. The most usual modification is that caused by inadequate treatment, and I continue to see many such cases in Liverpool. The history is always the same. The patient has been instructed to take quinine during his attacks, and for a week or two afterwards. This is insufficient, and the inevitable relapse occurs! But the patient seldom falls into the extreme condition of wholly untreated cases. The drug has not extirpated the infection, but it has checked each relapse as it occurs, and has controlled the anaemia and splenomegaly. Such especially is the condition of the infected sailors of whom we see so many in Liverpool. They still have relapses, but the spleen is not markedly enlarged and the anaemia not very pronounced.

Works written on malaria in temperate and often more civilised countries do not always give a complete picture of the disease as it occurs among poor natives in the tropics. This is due to the fact that the more general use of quinine in the former tends to abbreviate the course of the infection. On the other hand, the great majority of cases in the malarious villages of the tropics are cases of chronic malaria—untreated, subject to frequent reinfections, and with anaemic enlargement of the spleen and numerous relapses. In temperate climates, our cases are mostly in the early period of paroxysms; in the tropics they are mostly in the long-continued period of relapses and relapses.

(4) The parasites during the relapses.—The general observ
tion that the degree of fever depends upon the number of parasites suggests that when there is no fever the parasites are likely to be at least scanty. Hence, as is to be expected, in the rallies between relapses few sporids, and indeed very often none at all, can be discovered in the small quantities of blood examined under the microscope—though, of course, the gametids (which do not seem to produce fever) may still abound. Nevertheless, when the relapse occurs, the sporids again appear in detectable or large numbers. What happens to them when they disappear and reappear in this manner?

We can easily observe that the number of parasites, when they are numerous enough to be found, often varies largely. It is therefore equally easy to infer that when we can no longer find them, this is due simply to the fact that they have become too scarce to be found. But many writers seem to think that when they cannot find sporids none exist, and have therefore sought other explanations of the disappearance and reappearance referred to.

Years ago Marchiafava and Bignami suggested that when they disappear for long periods the parasites may become encysted somewhere in the inner organs; or that they may die out altogether, and that the relapse may be caused by spores which escape from phagocytes in which they have been living in a dormant condition. No evidence has been given for these views; yet it should be easy to obtain in the malaria of birds, which remain infected for months. In 1898 I examined many birds in vain for the supposed encysted forms.

Golgi, Mannaberg and others thought that crescents keep the infection alive during the rallies. Thus Mannaberg said [1894, p. 302]: “These relapses in localities free from malaria are to be explained only by the persistence of parasites possessing certain powers of resistance (probably the crescentic bodies) within certain tissues.” But why are any special powers of resistance required, and how explain relapses with the parasites which do not produce crescents? Many authors,
working, I believe, with unstained films, have described and figured sporulation of crescents; but others attributed this merely to post-mortem vacuolisation. We have never found sporulating crescents in stained films in Liverpool, though numbers of these bodies are examined in class. B. Grassi [1901] suggested that the relapses are caused by parthenogenetic reproduction in the gametids.

This idea was followed up by F. Schaudinn [1902]. A patient who had suffered long from *P. vivax* was attacked on 29th April and 1st May, and was found to contain both sporids and gametids. A rally now occurred, during which daily examination disclosed varying numbers of gametids only. On 25th May these parasites were more plentiful. Next day curious changes were noted in the female gametids, suggesting that they were producing spores similar to those ordinarily produced by the asexual sporids. The author considered this to have occurred independently of fertilisation by the male gametids, and to be due to parthenogenesis. The same day (26th May) the patient had a slight rise of temperature to 38.4°C, and in the evening ordinary young sporids were found. Next day only these forms occurred. On 28th May there was a typical attack with temperature reaching 40.7°C, and with the usual sporids. Next day only gametids were again found. The author carefully described the parthenogenetic forms and traced the corresponding changes in the nucleus.

These observations were hailed as an important discovery by many writers, especially zoologists. They have been partially repeated by Maurer [1902], Blum and Merz [1908], Harrison [1909] and others; and many of the younger and more confident workers have spent much time in attempts to verify them, or have seen objects like those described by Schaudinn. But the objects twice seen by Maurer are not in any way proved to be parthenogenetic forms; while those observed in six preparations by Blum and Merz are supposed by the authors to be more probably cases of production of gametids by gametids—another
hypothetical; and these authors do not agree with Maurer. Harrison admits that the supposed "gametochinetae" seen by him may be merely double infections of haematids by a gametid and a sporid. Craig [1906] thinks that "intracorpuscular conjugation" may maintain the infection.

It is easy to see under the microscope objects which suggest this or that hypothesis, but only the most patient and long-continued labours suffice to prove the truth. Schaudinn's case seems to me of doubtful value. I note especially that between 1st and 25th May the number of gametids was low, and was increased on the latter date. But this variation suggests that they were being produced all the time. The gametids are supposed to be produced from ordinary spores, so that we are forced to infer that a number of sporsids, some of them producing gametids, were present in the patient's body, although too few to be detected in the small quantities of blood examined by the author. On 25th May they probably increased in number sufficiently to induce a slight attack of fever, and were then mistaken for parthenogenetic gametids. On 28th May they produced a typical attack; and that is all. The supposed nuclear changes were reported on evidence of no great value. The cells were not actually observed undergoing the development which the author describes. He merely inferred the existence of the development from a study of different cells in what he thought were different stages of that development. Worst of all, no numerical estimates are given. The same author enunciated many other hypotheses on similar evidence.

I doubt whether parthenogenesis occurs with the parasites of malaria, for the following reasons:

(a) If it occurs in one species it ought to occur in all. It ought therefore to be easily observed in birds' malaria, and in crescents. I have been examining the latter for fifteen years and have never seen in them anything suggesting parthenogenesis. Yet they possess a definite and uniform outline which should
be much modified by such cellular changes as Schaudinn described. A. Carducci [1905], though favourably inclined towards the parthenogenetic speculation, failed after careful search in finding any evidence of it in crescents.

(b) I have frequently seen relapses occur in cases of P. falciparum in which no crescents at all could be found. Carducci notes the same (see section 15).

(c) In further experiments (see end of section 14) blood containing numerous crescents only was injected into healthy persons by capable observers without producing any infection whatever. Yet I showed in 1895-1896 that crescents live on ice and for hours under vaseline. Why then, if Schaudinn's hypothesis is true, did they not infect any of these four persons?

(d) If relapses are caused merely by some natural development in the parasites we should expect them to occur more or less independently of the state of health of the host—which does not seem to be the case (see subsection 6).

(e) If it occurs at all, parthenogenesis ought to be common enough to be demonstrable with ease and certainty.

This subject is of great importance in connection with the prevention of malaria. Crescents withstand much medication with quinine, and if they keep the infection alive in patients it follows that quinine loses much of its value as a public prophylactic against malaria. But, while I am quite ready to accept any evidence for it which may be offered, at present I do not think that the Grassi-Schaudinn speculation is even nearly proved.

The fact that the parasites disappear at each rally and reappear at each relapse is explained quite easily and sufficiently. In the rallies they become too few to cause fever or to be

1 H. M. Neeb [1909] in a paper just to hand shows much, but I think still quite conclusively, work in favour of parthenogenesis in crescents.
THE PARASITES DURING THE RALLIES

detectable in the small quantities of blood examined; in the
relapses they become numerous again. I cannot see that a
simpler or more satisfactory explanation is required. We
observe the same process in relapsing fever, tuberculosis,
trypanosomiasis and other diseases.

A good writer once said: "It is hardly conceivable that it
(the parasite) should remain in the general circulation, passing
through its ordinary cycle of existence, without causing any
symptoms whatever. Further, the failure of repeated examina-
tions of the blood of patients who have previously suffered
from malaria to reveal the presence of the parasite renders
this most unlikely." It is impossible to accept such a train
of thought. If 150,000 parasites cause but little fever in a
man of medium weight, 1,000 or 10 should cause none at all,
and yet will be quite sufficient to keep the infection alive in
him. But if the parasites are so few, what chance has the
medical man of finding a single one? If even 1,000 parasites
are present in a man of 10 stone weight, the chances are that
we must search 15,000,000,000 haematids before we find one
parasite. At the rate of 10,000 haematids a minute we shall
have to search for 1,500,000 minutes, or for twelve hours a
day for more than five years, before we succeed. Or we may
put it in this way—that 150,000 examinations, each of ten
minutes' duration, must be made.

* In seven autopsies on cases of "latent malaria," C. F. Craig
[1905] found only the ordinary parasites in the spleen. Four
of these contained malignant parasites, yet no crescents at all
were found in the spleen.

(5) Probable cause of the rallies and relapses.—According
to this simple hypothesis (which I will continue to adopt until a
better one is established) the rallies are probably due to a
great destruction of the parasites by some germicidal power
of the blood, or of their toxin by some antitoxic power, or
more generally at both. And the relapses are probably due
to decrease in both of these factors of resistance.
It is not within our province to discuss these factors now. The general experience that many cases improve without treatment, and merely after good food and rest in bed, proves that such factors exist; and, as already stated, if they did not exist every case would certainly perish.

Many diseases—tuberculosis, trypanosomiasis, relapsing fever, leprosy, etc.—exhibit such variations in intensity. We picture to ourselves a long struggle between the invaders and the opposing force—first one side triumphs and then the other, and death or recovery finally ends the contest.

Just as rest and good food encourage the resistance, so, probably, anything which weakens the patient—fatigue, chill, heat, dissipation, other sickness—tends to encourage the parasites. Educated patients often declare that their fever is brought on by such causes. Military surgeons recognize that when infected troops are despatched upon arduous military duties numbers of them begin to fall sick at once, even though it may not be the season of fresh infections. Travellers and planters complain of the same thing as regards their porters or coolies; and medical men notice the frequency of malarial relapses after typhoid fever, venereal diseases, childbirth, accidents, etc.

I think that external heat probably tends to encourage relapses. Although the temperature of the body remains much the same, the parasites may possibly be stimulated by the heat in some way, owing to the fact that warm climates are specially suitable to them and to their dissemination by mosquitoes. Thus in my experiments on birds in 1898, I noticed that when the birds were taken to the cool climate of the Himalayas their parasites greatly diminished, and when they were brought back again to Calcutta their parasites increased again. In the hot weather in Calcutta 11/2% of the sparrows examined contained *P. damoensisi*, but early in the cool weather few were found to be infected. This point requires exact experimental study. A. Caccini [1902] thinks...
that excess heat does not have much effect, but notes the frequency of relapses in benign tertian in spring, and it seems to me that the onset of warm weather rather than the heat itself is most likely to be the encouraging factor, since the germicidal power is probably heightened after the first relapses in spring. It is interesting to note that in India there is generally a small but well-marked rise in the admission rate of troops at the commencement of the warm weather in March to April. For example, I take at random the Native Troops on the North-West Frontier, Indus Valley, and North-West Rajputana ("Reports of the Sanitary Commissioner with the Government of India") and give the averages for the three years 1900-1902.

**AVERAGE ADMISSIONS.**

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td></td>
<td></td>
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<tr>
<td>Jun</td>
<td>270</td>
<td>293</td>
<td>303</td>
<td>302</td>
<td>261</td>
<td>230</td>
<td>222</td>
<td>217</td>
</tr>
<tr>
<td>Jul</td>
<td>230</td>
<td>255</td>
<td>242</td>
<td>238</td>
<td>222</td>
<td>210</td>
<td>207</td>
<td>203</td>
</tr>
</tbody>
</table>

Here there is a marked increase between March and April, that is, at the commencement of the hot dry weather, long before the advent of the breeding season of Anopheles. It may, however, be due to the awakening of infected hibernating mosquitos (section 21).

4 Why, if the germicidal power is strong enough to destroy large numbers of the parasites, does it not destroy all of them? I presume that, as in other forms of life, the hardest individuals who succeed in withstanding the opposing forces unless they are too strong; that a few of the plasmodia survive until the germicidal power is fully developed—when the entire brood is exterminated.

What is it that determines the length of the rally, or apyrexial period? Probably (a) the number of plasmodia left alive at the end of the previous attack, and (b) the strength of the germicidal power of the patient. If the parasites are reduced to about the number of merozoites originally inoculated, and the germicidal power weakens rapidly, the former will now multiply again at a rate somewhat similar
to their first rate of proliferation—so that the length of the
apyrexic period should be roughly equivalent to the original
incubation period. If the germicidal power is strong, or is
fortified by quinine, the plasmodia left alive after the previous
attack should multiply so slowly that the apyrexial period may
be indefinitely prolonged. Under such circumstances the
parasites may perhaps continue to breed for months in a
patient, without causing the smallest symptoms, and yet, if
the germicidal power is reduced for a moment, may be able
at any time to multiply again sufficiently to produce another
attack. The same thing probably happens with irregular or
insufficient quinine medication. The long intervals which fre­
quently occur can be explained equally well on this hypothesis.

We do not know why the resistance of the host should
be affected by his general state of health or by external
conditions. That such is the case affords another argument
against the idea that the relapses are due merely to some
normal development of the parasites. The study of immunity
in malaria should yield important facts for the study of
immunity in general. I merely touch upon the subject here.

Cases are often reported in which the patient during the
relapses suffers from malaise, dyspepsia, and so on, rather
than from fever, although the parasites are numerous enough
to be found. In such, I presume, the antitoxic power of the
blood has become better developed than the germicidal power.

Cases in which a relapse immediately follows a chill or accident
are explained perhaps by the hypothesis that the chill or accident has immediately reduced the antitoxic (not necessarily
the germicidal) power of the blood.

(6) Frequency of the relapses.—All clinicians recognise that
in untreated or badly-treated cases a considerable number of
relapses may occur before complete recovery is established.
Cases giving a history of say three to ten relapses are very
common. But we are indebted to A. Calceld [1902] for
giving us a very able and full analysis of this question. In
1899-1901 he was entrusted by Professor Ballori, Director-General of the Hospitals in Rome, with the care of a special department for the study of malaria, and set himself to the task of examining these questions methodically. The cases studied by him were as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>First Attacks</th>
<th>Relapses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartan</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Benign Tertian</td>
<td>1,086</td>
<td>934</td>
<td>2,020</td>
</tr>
<tr>
<td>Malignant</td>
<td>2,275</td>
<td>1,429</td>
<td>3,704</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>3,886</td>
<td>2,693</td>
<td>6,579</td>
</tr>
</tbody>
</table>

Many of the cases were given quinine, so that this proportion will not accurately represent the proportion of relapses in untreated cases—which should be much larger. The author excluded all cases in which the parasites were not found. He endeavored to ascertain as exactly as possible the history of each case, not only by enquiry of each patient, but by reference to hospitals and localities where they had been treated; he kept many cases in hospital for long periods, and he gives a careful record of his results. I will mention here only his untreated cases.

Two cases of benign tertian, untreated, were kept under observation in bed in hospital for nine months. The following table gives the duration in days of their successive relapses:

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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>1</td>
<td>16</td>
<td>14</td>
<td>19</td>
<td>15</td>
<td>17</td>
<td>15</td>
<td>17</td>
<td>15</td>
<td>17</td>
<td>15</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

Both patients were robust, had the same diet, and were not allowed to suffer from cold or damp or intercurrent affections. Nineteen similar cases studied for shorter periods showed the same phenomena. The author notes that out of 120 untreated cases of benign tertian, the relapses occurred more frequently in the spring (March to May). He thinks that the relapses continue from 5 to 18 days, which he calls apyrexial periods or short intervals. But he also notes and distinguishes rallies of...
long interval, lasting 3 to 4 months, which he says occurred in 152 persons who had not revisited malarious places in the meantime. The rally lasted under 2 months in 60 cases; under 30 days in 29 cases; 90 days in 20 cases; and from 90 to 120 days in the remaining cases.

He also quotes the case of a band of 15 Calabrian workmen who had become infested at Foggia in July 1900, and had subsequently taken quinine until December. On 8th September 1901, 14 months after the first infection, 6 of these men were exposed to a severe wetting with rain, while the remaining 13 found shelter. On 10th September and the six following days, every one of these 62 men was attacked with relapses. The intervening rallies since their last attacks had lasted for 7 months in 2 of the men; for 3 months in 3; for 8 months in 12; for 9 months in 10; for 10 months in 15; and for 13 months in 20. Those who had not been wetted by rain escaped. It is supposed that none of the cases had been subject to reinfection.

In quartan the author found that out of 118 cases kept without treatment relapses occurred only in 8 which had been exposed to chills and other predisposing causes. He thinks that quartan relapses chiefly as a consequence of such causes—unlike tertian, which relapses under any conditions. The length of the rally depends upon the care which has been taken of the patient; but the author quotes six cases of relapse occurring after long intervals (6 to 10 months). He says also that in some cases of experimental inoculation of quartan by him (no reference) the incubation period could be prolonged at pleasure by keeping the subject at rest in bed, etc.

Regarding malignant fever, Caccini gives the following lengths of the rallies in 44 untreated persons:

<table>
<thead>
<tr>
<th>Days</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
</tr>
</tbody>
</table>

The author suggests that there is some radical difference between relapses at short and at long intervals, but I cannot
FREQUENCY OF RELAPSES

He agrees with all observers in attaching great importance to the determining factors of relapse, which he says are:

1. Absence of good food and health,  
2. Gastro-intestinal troubles,  
3. Fatigue,  
4. Traumatism,  
5. Sudden chills, damp, and wetting,  
6. Change of climate,  
7. Certain foods and medicines due to intestinal disturbance,  
8. Intercurrent sickness.

To these I would add:

9. Anxiety, sorrow, shock or fright,  
10. Alcoholism and other excess,  
11. Sudden exposure to a tropical sun,  
12. Premature cessation of quinine.

It is, of course, understood that these determinants act by reducing temporarily the host's resistance, but we do not know exactly how they do so.

Caccini endorses the common opinion that quartan and tertian, especially the former, are most prone to relapses. In malignant, the original illness is more severe and (probably for this reason) relapses are not so common. I will refer to his important results with quinine in section 23.

Celli gives a useful table showing primary cases, relapses and pernicious cases in the Roman Hospitals for 1892-1898. The following are the totals for the seven years:

<table>
<thead>
<tr>
<th>Month</th>
<th>Primary</th>
<th>Relapses</th>
<th>Pernicious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>86</td>
<td>58</td>
<td>4</td>
</tr>
<tr>
<td>Feb</td>
<td>4</td>
<td>35</td>
<td>8</td>
</tr>
<tr>
<td>Mar</td>
<td>67</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Apr</td>
<td>6</td>
<td>35</td>
<td>9</td>
</tr>
<tr>
<td>May</td>
<td>74</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>June</td>
<td>793</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>July</td>
<td>809</td>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>Aug</td>
<td>676</td>
<td>26</td>
<td>66</td>
</tr>
<tr>
<td>Sept</td>
<td>2,912</td>
<td>52</td>
<td>519</td>
</tr>
<tr>
<td>Oct</td>
<td>1,156</td>
<td>21</td>
<td>69</td>
</tr>
<tr>
<td>Nov</td>
<td>657</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>Dec</td>
<td>3,875</td>
<td>130</td>
<td>133</td>
</tr>
<tr>
<td>Totals</td>
<td>10,987</td>
<td>645</td>
<td>1,388</td>
</tr>
</tbody>
</table>

Thus, excluding the pernicious attacks, out of a total of 33,307 cases, 75% were reported to be primary and 25% relapses—that is, three to one.
Relapses are referred to in many other works, but the information given is scanty. The illness being generally slighter, patients do not often come to hospital in consequence of it; and in most cases quinine distorts the clinical picture (section 22).

Relapses after long intervals are frequently mentioned. The case of P. T. Manson (section 16, case 5), who had a relapse nine months after the original infection, followed by three months' quinine treatment, is well known. In one case at the Royal Southern Hospital I found the parasites in a patient who said that he had left the tropics four years previously (records unfortunately lost). In Britain we have many returned officials who say that they continue to have occasional attacks after return from malarious colonies—more than twenty years have been mentioned to me by three persons; but as each attack lasts only for a day or two it is generally impossible to verify the point microscopically. My father left India in 1880, but in 1899 still complained of occasional attacks. A little later I witnessed one of these—a sudden severe rigor followed by high fever and a typical sweating stage. The blood was not examined, but the paroxysm was almost certainly a quartan or tertian one. So far as I remember there was no determining factor in this case.

21. Average Duration of Untreated Infections.—Persons may therefore remain infected for several, and possibly for many years; just as some may recover spontaneously after the first series of attacks. But from the public health point of view an important question remains to be answered, namely, how long does the infection continue in untreated cases on the average? That is, if 1,000 persons, simultaneously infected, were to be removed simultaneously to a perfectly healthy area, where they are kept untreated, how long would their infections continue? It is impossible to say at which particular moment the last parasite dies out in a patient's blood, and no adequate researches have been made on the point. We are therefore forced to rely upon certain calculations.
The cases of malaria at Ismailia from 1900-1905 are given officially as follows:

<table>
<thead>
<tr>
<th>Years</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>2,281</td>
</tr>
<tr>
<td>1901</td>
<td>1,551</td>
</tr>
<tr>
<td>1902</td>
<td>37</td>
</tr>
<tr>
<td>1903</td>
<td>32</td>
</tr>
</tbody>
</table>

In 1901-1902 quinine was largely distributed in the town, but after my visit at the end of 1902 the Anophelines were banished, the quinine also being continued to those who took it. Since 1903, and probably since 1902, there has been no endemic malaria, such cases as occur being found only in persons infected outside, or being merely relapses. Hence we infer, as a very rough calculation, that of the 1,551 persons who were ill in 1902, less than $\frac{1}{2}$ remained ill in 1903, and less than $\frac{1}{10}$ remained ill after two years. But here quinine expedited the recovery on one side of the account; while on the other side of it many of the cases that remained were probably due to external infection.

Another way to estimate the reduction is, I suggest, to consider the statistics of some country where fresh infections suddenly cease owing to the abrupt onset of a sharp winter and the consequent cessation of mosquito breeding and mosquito biting. I select as an example the Punjab, a large malarious area in the extreme north-west corner of India, and give the figures of admissions furnished by the annual "Reports of the Sanitary Commissioner with the Government of India."

The years 1899 to 1903 have been selected because after the latter date quinine began to be administered much more regularly. Nevertheless, subsequent figures show very similar monthly variations—as in fact are shown by the same statistics for other parts of India.

The ratios under each monthly average are obtained by dividing by it the following monthly average—so that these ratios give the monthly factor of increase or decrease in the number of admissions. The striking regularity with which the maximum is reached in October and the minimum in February will be observed.
### A. European Troops—(Table X.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Strength</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>16,806</td>
<td>158</td>
<td>155</td>
<td>150</td>
<td>140</td>
<td>115</td>
<td>115</td>
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<td>140</td>
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</tr>
<tr>
<td>1921</td>
<td>16,806</td>
<td>155</td>
<td>150</td>
<td>140</td>
<td>135</td>
<td>120</td>
<td>115</td>
<td>120</td>
<td>130</td>
<td>140</td>
<td>150</td>
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<td>16,806</td>
</tr>
<tr>
<td>1922</td>
<td>16,806</td>
<td>150</td>
<td>140</td>
<td>135</td>
<td>130</td>
<td>120</td>
<td>115</td>
<td>120</td>
<td>130</td>
<td>140</td>
<td>150</td>
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<tr>
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<td>130</td>
<td>140</td>
<td>150</td>
<td>160</td>
<td>180</td>
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</tr>
<tr>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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### B. Native Troops—(Table XXXV.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Strength</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
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<tbody>
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<td>550</td>
<td>570</td>
<td>545</td>
<td>535</td>
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<td>545</td>
<td>550</td>
<td>550</td>
<td>550</td>
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<tr>
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<td>570</td>
<td>545</td>
<td>535</td>
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<td>545</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>40,812</td>
</tr>
<tr>
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<td>515</td>
<td>550</td>
<td>570</td>
<td>545</td>
<td>535</td>
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<td>550</td>
<td>40,812</td>
</tr>
<tr>
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<td>550</td>
<td>570</td>
<td>545</td>
<td>535</td>
<td>530</td>
<td>530</td>
<td>535</td>
<td>545</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>40,812</td>
</tr>
<tr>
<td>Ratio</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Year</td>
<td>Strength</td>
<td>Jan</td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
<td>June</td>
<td>July</td>
<td>Aug</td>
<td>Sept</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
<td>Total</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
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<td>------</td>
<td>-----</td>
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<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>1899</td>
<td>15,110</td>
<td>505</td>
<td>566</td>
<td>447</td>
<td>286</td>
<td>322</td>
<td>256</td>
<td>607</td>
<td>727</td>
<td>581</td>
<td>627</td>
<td>605</td>
<td>447</td>
<td>5,019</td>
</tr>
<tr>
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<td>15,110</td>
<td>505</td>
<td>566</td>
<td>447</td>
<td>286</td>
<td>322</td>
<td>256</td>
<td>607</td>
<td>727</td>
<td>581</td>
<td>627</td>
<td>605</td>
<td>447</td>
<td>5,019</td>
</tr>
<tr>
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<td>15,089</td>
<td>504</td>
<td>529</td>
<td>579</td>
<td>322</td>
<td>435</td>
<td>475</td>
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<td>506</td>
<td>627</td>
<td>605</td>
<td>447</td>
<td>4,989</td>
</tr>
<tr>
<td>1902</td>
<td>15,089</td>
<td>504</td>
<td>529</td>
<td>579</td>
<td>322</td>
<td>435</td>
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<td>506</td>
<td>627</td>
<td>605</td>
<td>447</td>
<td>4,989</td>
</tr>
<tr>
<td>Average</td>
<td>15,089</td>
<td>504</td>
<td>529</td>
<td>579</td>
<td>322</td>
<td>435</td>
<td>475</td>
<td>607</td>
<td>670</td>
<td>506</td>
<td>627</td>
<td>605</td>
<td>447</td>
<td>5,019</td>
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<tr>
<td>Ratio</td>
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<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>670</td>
<td>6,806</td>
</tr>
</tbody>
</table>
For the European troops the maximum (835) is 6.47 times the maximum (129), which occurs four months later. For the native troops, the maximum (2,955) is 6.41 times the minimum (461)—almost the same. For the prisoners the maximum (1,045) is 3.93 times the minimum (266)—a smaller ratio.

Thus, for 1,000 admissions in each class during October the following numbers were admitted in February—

<table>
<thead>
<tr>
<th>Class</th>
<th>October</th>
<th>February</th>
</tr>
</thead>
<tbody>
<tr>
<td>European troops</td>
<td>1,000</td>
<td>129</td>
</tr>
<tr>
<td>Native troops</td>
<td>2,955</td>
<td>174</td>
</tr>
<tr>
<td>Prisoners</td>
<td>1,045</td>
<td>276</td>
</tr>
</tbody>
</table>

A certain amount of quinine was doubtless given to all these classes, and many of the Europeans were probably moved to hill stations after April to May. It is easy to understand the small rate of recuperation of the prisoners—a constantly changing class drawn from the lowest ranks of the population and depressed by their imprisonment. Hence I infer that the rate of recovery of the European and native troops during the four months is probably too favourable for an estimate of the same rate among a large untreated native population. On the other hand, the quinine treatment of the prisoners may be cancelled by their circumstances, so that their rate of recovery should be something similar to that of the general population. We may therefore, perhaps, assume as a rough but convenient estimate for the latter that what may be called the reduction factor in about 0.25 in four months—that is, that 1,000 cases should be reduced to 250 in that time by spontaneous improvement.

We observe in the statistics given above that there is an almost constant but slow increase in the admissions from February onward. Whether this is at first due to heat relapses or to infections by hibernating Anophelines (section 20) is not known; but if no such increase were to take place, we might suppose that the same rate of recovery would hold for
the rest of that year. In other words, we might suppose that any number of patients brought to England would be reduced by recovery to one quarter every four months—that 1,000 cases would become 250, 62.5, in four, eight, twelve months respectively, and so on. This is, I fear, a very rough estimate, but I know of no other method of making any estimate at all.

Hence we may perhaps infer that 3/4 of our untreated cases will recover in four months, 15/16 of them in eight months; 31/32 of them in a year, and so on. But these figures are based upon the past statistics of the Punjab—that is, upon those of natives, most of whom have probably had malaria in childhood. What may happen in the case of a completely non-immune and untreated population I cannot say. For such we might adopt a still slower rate of recovery, say 1/2 or 3/4, every three months; that is, 1/2 would recover in three months, 7/8 in six months, 15/16 in nine months, and 31/32 in a year. On the whole, this is probably the nearest estimate.

Celli [1867] gives the admissions into the Roman Hospitals during thirteen of the years between 1804 and 1896—numbering nearly 93,000 altogether. I subjoin the monthly totals for the reader to study in connection with the above remarks.

<table>
<thead>
<tr>
<th>Month</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>583</td>
<td>526</td>
<td>304</td>
<td>123</td>
<td>84</td>
<td>375</td>
<td>615</td>
<td>178</td>
<td>127</td>
<td>53</td>
<td>104</td>
</tr>
</tbody>
</table>

22. Enlargement of the Spleen and Liver.—This is a condition of importance in the prevention of malaria, as it often enables us to estimate the amount of the disease in a locality. We must now note the following points regarding it.

The average weight of the spleen of a healthy man of 60 kilograms in weight is estimated to be 171 grams (Virchow), or 2.83% of body-weight. In healthy adults the edge of it cannot be felt under the ribs, but the reader should note that this can often be done in small infants. The organ commences to enlarge during even the fe-
paroxysm of malarial fever, the increase in the size of spleen, dullness being quite appreciable. In the first apyrexial period the enlargement decreases, but as attack follows attack the sum of the successive increments is greater than that of the successive decrements, so that a more and more marked tumour results. Innumerable measurements have been recorded.

Kelsch and Kiener [1889] state that in eighty autopsies they found the weight to vary from 400 to 1,500 grams, and to average 914 grams (chronic malaria).

I think that even small and irregularly administered doses of quinine tend to check the increase very much. Thus in untreated native children one often finds the organ an inch or more below the ribs after a few attacks, while there is frequently no enlargement in Europeans even after many attacks. In sailors who have reached Liverpool after several or months' fever on the homeward voyage from West Africa, we find as a rule scarcely any enlargement. In 1895 my regiment in Secunderabad, India, was full of malaria as proved by the microscope and the clinical symptoms, but on making a spleen census by order of the authorities I found only four men with enlarged spleen out of about eight hundred. In both these instances a certain amount of quinine is or was given—not enough to cure the patient, but enough to check the splenomegaly.

The pathological changes are discussed in detail in the text-books and need not be described here. Laveran [1907, p. 391] considers the pathology and seems to think that the enlargement is due to local irritation caused by the accumulation of the parasites in the organs, which is their "siège d'embarras." Others connect the enlargement with the defensive process. The arguments are far from conclusive on either side.

On the whole, from general observation, I consider that the following propositions are probably true—

(1) That in a given number of infections of the same
ENLARGEMENT OF THE SPLEEN

That in a given number of infections of the same duration (a) in children and (b) in adults, the children will show a greater degree of splenomegaly.

(1) That in a given number of infections of the same duration (a) in Indo-Europeans and (b) in Negroes, the former will show a greater degree of splenomegaly.

I cannot speak regarding Mongolians.

(2) That in a given number of infections of the same duration (a) in untreated persons and (b) in persons of the same age and race treated even slightly with quinine, the former will show a greater degree of splenomegaly.

(3) That in a given number of infections of the same duration (a) in persons infected only once, and (b) in persons who have been subject to repeated infections, the latter will show the greater degree of splenomegaly.

That the number of parasites tends to vary inversely as the degree of splenomegaly; that is, that the parasites tend to die out in persons with very large spleen.

(6) That a hot and damp climate, or insufficient food, or certain diets, or bad drinking water may possibly favour the development of splenomegaly; in other words, that the degree of splenomegaly may not always be an exact measure of the amount of malaria in a locality.

I cannot give anything approaching proof of these propositions, but merely suggest them for future consideration and investigation.

On the other hand, some general facts have been more strictly ascertained. Before considering them we should remember that many of the older observations have been invalidated by the discovery in 1903 that kala-azar, a disease which causes great enlargement of the spleen and liver and abounds in parts of India, Algeria and other countries, is not
THE PARASITIC INVASION IN MAN [Sec. 6.3]

malaria, but is due to a different organism, *Leishmania donovani*, Laveran. Before this date the two diseases were frequently confounded, as, for instance, by myself in my report on kala-azar [1899]. If therefore we wish for accurate figures we must first ascertain whether kala-azar is present or not, or at least whether it is very prevalent. This is generally not difficult, for the following reasons:—

1. Kala-azar is extremely fatal, whereas malaria is benign; so that the presence of the former is soon felt in a locality.

2. The parasites of both diseases can be detected during life and post-mortem.

3. The symptoms of kala-azar, though somewhat similar to those of malaria, are much more intense. The patients often have a look of suffering and melancholy not so frequently observed in malaria. I was much struck with this difference when comparing splenomegalous children in Greece and Mauritius with those suffering from kala-azar in Assam.

In the absence of this disease, then, we may generally ascribe most of the cases of enlargement of the spleen to malaria, especially if they are numerous. They are generally extremely numerous in most malarious localities where quinine is not much taken.

In 1907-1908 Major Fowler and I, assisted by the Sanitary Department and the medical men of Mauritius, made a large "spleen census" in that colony. We examined children of fifteen years of age and under, in all parts of the island. Out of an estimated total of 182,000 such children we tested 31,022, and found enlargement of the spleen in 10,595, or more than one-third (34 1/100). Moreover, in 30,137 we recorded the degree of enlargement, and found that it was small in 4,381, or 14 1/100; medium in 3,479 or 11 1/100; and great in 2,566 or 8 1/100—a total of 10,426 with enlargement.

This differentiation of degree suggests the possibility of
ENLARGMENT OF THE SPLEEN

obtaining a figure which I call the average spleen index. Taking a normal spleen at 171 grams, a very large spleen of 1,500 grams would be about nine times that size. We may therefore define a small enlargement as being about three times the normal size; a medium enlargement about six times the normal; and a great enlargement about nine times the normal—the same ratios holding for children also. Thus in order to find the average spleen, we multiply the numbers under each heading by the size-ratio, and add the results to the number of children with no enlargement, and divide by the total number of children examined. We thus have $(19,711 + 4,381 \times 3 + 3,479 \times 6 + 3,155 \times 9) = 23,454$ the average spleen for Mauritius (section 3).

From these and other data I compiled the following table (1908) showing the relation between the spleen rates and altitude, and the spleen rates and the general death rate in Mauritius.

### Spleen Rates According to Altitude (Mauritius)

<table>
<thead>
<tr>
<th>Altitude (in Feet)</th>
<th>Children Examined</th>
<th>Total Spleens</th>
<th>Spleen Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000-1,100</td>
<td>2,512</td>
<td>1,031</td>
<td>1031</td>
</tr>
<tr>
<td>1,100-1,200</td>
<td>3,078</td>
<td>1,128</td>
<td>705</td>
</tr>
<tr>
<td>1,200-1,300</td>
<td>3,534</td>
<td>1,221</td>
<td>347</td>
</tr>
<tr>
<td>1,300-1,400</td>
<td>4,090</td>
<td>1,312</td>
<td>327</td>
</tr>
<tr>
<td>1,400-1,500</td>
<td>4,646</td>
<td>1,404</td>
<td>302</td>
</tr>
<tr>
<td>1,500-1,600</td>
<td>5,202</td>
<td>1,506</td>
<td>288</td>
</tr>
<tr>
<td>1,600-1,700</td>
<td>5,758</td>
<td>1,608</td>
<td>274</td>
</tr>
<tr>
<td>1,700-1,800</td>
<td>6,314</td>
<td>1,710</td>
<td>268</td>
</tr>
<tr>
<td>1,800-1,900</td>
<td>6,870</td>
<td>1,812</td>
<td>262</td>
</tr>
<tr>
<td>1,900-2,000</td>
<td>7,426</td>
<td>1,914</td>
<td>258</td>
</tr>
</tbody>
</table>
The exceptionally high figures at an altitude of 1,400 feet (426 meters) were due to a serious local outbreak at the large village of Phoenix in Plaines Wilhelms district, most of which is high and healthy. It should be understood that the higher altitudes in Mauritius are plateaux rather than sloped hillsides, so that the variation is probably due merely to difference of climate. The accepted rule is that the temperature falls 1°F. for every 300 feet (or 1°C. for 164.6 meters) of altitude.

A still larger spleen census was carried out in Ceylon towards the end of 1906 by the orders of the Principal Civil Medical Officer (Sir Allan Perry). He estimated that the total number of children under fifteen years in that island were 1,622,766, and the following table gives the result of the census (as reported by the Advisory Committee for the Tropical Diseases):

<table>
<thead>
<tr>
<th>Class</th>
<th>Districts</th>
<th>Mean spleen rate (average 1905-8)</th>
<th>Spleen rate</th>
<th>Average spleen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estates only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pamplemousses</td>
<td>37.3</td>
<td>39.6</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Flacq</td>
<td>37.9</td>
<td>39.6</td>
<td>38.1</td>
</tr>
<tr>
<td></td>
<td>Grand Port</td>
<td>32.0</td>
<td>35.0</td>
<td>33.6</td>
</tr>
<tr>
<td></td>
<td>Savanne</td>
<td>30.5</td>
<td>32.7</td>
<td>31.9</td>
</tr>
<tr>
<td></td>
<td>Black River</td>
<td>30.5</td>
<td>32.7</td>
<td>31.9</td>
</tr>
<tr>
<td></td>
<td>Black River</td>
<td>38.5</td>
<td>40.6</td>
<td>38.6</td>
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<tr>
<td></td>
<td>All Classes</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Average of the above</td>
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<td>34.0</td>
<td>32.8</td>
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<td></td>
<td>Port Louis</td>
<td>37.8</td>
<td>41.5</td>
<td>39.7</td>
</tr>
<tr>
<td></td>
<td>Pamplemousses</td>
<td>37.8</td>
<td>41.5</td>
<td>39.7</td>
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<tr>
<td></td>
<td>Flacq</td>
<td>39.5</td>
<td>42.2</td>
<td>40.9</td>
</tr>
<tr>
<td></td>
<td>Grand Port</td>
<td>38.5</td>
<td>42.2</td>
<td>40.9</td>
</tr>
<tr>
<td></td>
<td>Savanne</td>
<td>35.2</td>
<td>39.5</td>
<td>37.8</td>
</tr>
<tr>
<td></td>
<td>Black River</td>
<td>34.2</td>
<td>38.7</td>
<td>37.4</td>
</tr>
<tr>
<td></td>
<td>Plaines Wilhelms</td>
<td>47.9</td>
<td>51.4</td>
<td>49.6</td>
</tr>
<tr>
<td></td>
<td>Average of the above</td>
<td>40.3</td>
<td>43.5</td>
<td>42.0</td>
</tr>
</tbody>
</table>

The accepted rule is that the temperature falls 1°F. for every 300 feet (or 1°C. for 164.6 meters) of altitude.
The spleen enlargement figures correspond closely with those obtained in Mauritius. They give not only valuable information regarding the local prevalence of malaria, but show how enormously widespread the disease must be—for neither Ceylon nor Mauritius can be called very extremely malarious. The figures in Ceylon were collected after the malaria season, and those of Mauritius during the early part of the season.

The correspondence between the spleen rate and the number of persons found to contain the parasites will be discussed in section 31 (2).

According to theory the spleen rate should fall with the distance from marshes. This point was carefully worked out by Major Fowler and myself in the outbreak at Phoenix, Mauritius. We found, not only that such a fall occurred, but that it was so extremely rapid and marked as to be beyond all possibility of chance distribution (section 31 (2) and maps).

The older writers lay down that the spleen is generally enlarged in malaria. Kelsch and Kiener (1889) say that its average weight is 2-3 kilograms, but that it may weigh up to...
4 kilograms; but they worked in Algeria, and it is quite possible that there, as elsewhere, cases of kala-azar were included. I was struck both in Greece and in Mauritius, where kala-azar is not supposed to exist, with the absence of any marked enlargement of the liver in the great majority of the children who had splenomegaly. More definite data are required on this subject.

23. The Effect of Quinine.—After the earlier physicians had established the utility of cinchona for malaria it began to be much discredited owing to its employment in doses too small to be effective. This error was rectified by Maillot [1834], who after a long struggle persuaded the medical profession to adopt larger doses in consequence of his experience in Algeria. But up to the end of last century, another error, equally great, was very generally made—the drug was not continued long enough to prevent relapses. When I went to India in 1857 it was the rule in military practice to return soldiers to duty three days after the cessation of fever. I believe that I was one of the first to call attention to this absurdity [1896, p. 43]. When I myself was infected next year I prescribed for myself a rigorous quinine treatment for four months, and had no relapses in consequence; and I have always taught this rule since then. The practice is now much better, but I still see numerous patients, especially from West Africa, who have been enjoined to take quinine for a fortnight after recovery! Needless to say, haemoglobinuria is often the result. A third error, still often made, is to withhold the drug until the fever has fallen.

Much work has been done on the absorption and elimination of quinine by the body—more recently by Kleine [1901], Jacangeli [1903], Mariani [1903–1904], Molvigiana [1905], Giemsa and Schaumann [1907] and others. The absorption is measured by the elimination, which takes place principally through the urine, in which the presence of the drug is easily
revealed by chemical analysis, and the results may be summarised sufficiently for public health work as follows:—

After intramuscular injection, cinchonism follows in a few minutes. Baccelli, who first suggested such injections, employed solutions of 1 gram of quinine in 10 parts of physiological salt solution—to be used only in severe cases.

After being taken by the mouth, the first traces of the drug may begin to appear in the urine in about fifteen minutes; but this period varies largely for different salts. The maximum elimination occurs between four to twelve hours after ingestion. Most of the drug is eliminated before thirty-six hours, but traces of it may be found even after nine days. Only about 1/3 of the dose escapes destruction by the body. The more soluble salts appear much more quickly in the urine than the less soluble ones, but the latter are finally absorbed as well as the former. So also, the salts are more quickly absorbed from an empty stomach; but the total amount absorbed from a full stomach is finally quite as large. Given in repeated small doses, the drug appears to be better absorbed than when it is given in a single dose of the same total weight.

After intramuscular injection, the salts are not absorbed so quickly, especially if given in strong solution. This is due to local precipitation (Giemsa and Schaumann). Thus while nearly 45% of quinine taken by the stomach may be eliminated in three days, only about 12% given intramuscularly in a 1:1 solution is eliminated in the same time. But with a 1:10 solution, about 25% of the salt (bichloride) is eliminated after intramuscular injection.

On the other hand, D. Sandro [1909] favours intramuscular injection because absorption through the liver is thus avoided. He also finds that the drug remains longest in the spleen (twenty hours).

After rectal injection, quinine appears in the urine in twenty-five minutes.

As the drug is not completely eliminated for several days.
THE PARASITIC INVASION IN MAN [SECT.

is cumulative in its action; so that a daily dose will keep the blood impregnated with about twice as much as is given at each dose [from Mariani, 1904]. Fever does not affect the absorption, but gastro-intestinal troubles do so if severe enough.

The following table shows when some of the various salts appear in the urine:

<table>
<thead>
<tr>
<th>Salt</th>
<th>Equivalent of quinine</th>
<th>Solubility</th>
<th>Appears in urine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicarbonate</td>
<td>7.5%</td>
<td>1/10</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Hydrochloride</td>
<td>3%</td>
<td>1/40</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Acetate</td>
<td>8%</td>
<td>3</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Citrate</td>
<td>1/8</td>
<td>2</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Sulfate</td>
<td>1/820</td>
<td>3</td>
<td>45 minutes</td>
</tr>
<tr>
<td>Tannate</td>
<td>31/500</td>
<td>1</td>
<td>180 minutes</td>
</tr>
<tr>
<td>Quinine</td>
<td>0.05</td>
<td>4</td>
<td>12,000 minutes</td>
</tr>
</tbody>
</table>

For further details the laborious papers referred to above, especially those of Mariani and Giemsa and Schaumann, should be consulted.

In large enough doses quinine produces ringing in the ears, deafness, giddiness, headache, dilatation of the pupils, urticaria and erythema, and, in poisonous doses, convulsions, muscular weakness and amnesia. A very small percentage of people are unable to take even small doses; Dr Macalister had a case in the tropical clinic of the Royal Southern Hospital at Liverpool who could not endure even 0.03 grams. I have observed in experiments on myself that quinine taken just before a meal causes tinnitus in about half an hour, thus proving its rapid absorption; but taken after a meal it does not produce this effect so quickly, while it tends to cause much dyspepsia, especially if given in pill form, and leaves a

Very variable figures are given. I quote some of those furnished to me by Howards & Sons.

G. Baermann has recently reported a death due to two doses of 1/2 gram of quinine hydrochloride—collapse, blood in dejecta, extravasation in organs.

I have just seen a patient who confessed to the rather exceptional drug-habit of quinine. He acquired a craving for it, and found great difficulty in breaking himself of the habit.

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taste in the mouth which remains until the next meal. For myself, therefore, I always prefer to take it just before meals, especially before breakfast. This is also often the best time, according to Torti's law, for destroying the plasmodia.

The action of quinine upon the parasites has been studied by many observers. Binz (1867) was the first to study the effect of weak solutions of quinine on Protozoa. Laveran states that a 1/10,000 solution kills the plasmodia in vitro. Romanowsky and Mannherz (1894) found that in patients who had been taking quinine the parasites possessed badly staining nuclei, that many of the spores within the sporocysts were dead, and that the understained parasites had a peculiar appearance. Numerous studies have been made subsequently on the subject, as by Ziemann (1906) and Craig (1906), which give a somewhat different picture of the death-process. Nearly all observers have agreed that quinine exerts much less influence on the gametids, especially the crescents, than upon the sporids, though Ziemann thinks that the male gametids are more easily affected. Many of the younger writers ascribe relapses to parthenogenesis in gametids which survive all quinine treatment in this manner. Guadile and Martinaco (1901) state that as much as 2.5 grams of quinine in single dose, or 10-15 grams daily, are not sufficient to banish crescents. I note that it is not always easy to state that the observed forms are really due to quinine and not to the germicidal action of the blood, and indeed that they are really abnormal forms at all; and also that strict enumerative methods have not been used.

An important point in connection with the prevention of malaria is that Bignami and Bastianelli, Guadile and Martinaco, and Schaudinn (1903) have succeeded in infecting Anophelines from patients who had been taking quinine. Schaudinn's case had been taking 1 gram thrice a week. Ziemann remarks that this suggests that the male gametids are not destroyed as he thought. It also suggests that cases of crescents are likely to prove sources of infection in spite of energetic treatment.
The article of Caccini [1902], which I quoted in part in section 20, gives valuable information on the effect of quinine treatment on the prevention of relapses, and therefore on the extermination of the invasion. After all, this is the most important part of the subject from the point of view of preventive medicine. He summarises his cases of benign tertian as follows:

1. Of 145 cases treated early and systematically a relapse occurred in 13.5%.
2. Of 210 cases treated systematically, but started somewhat late, a relapse occurred in 30%.
3. Of 100 cases with daily quinine, a relapse occurred in 10.5%.
4. Of 30 cases treated with quinine at height of fever, a relapse occurred in 80%.
5. Of 35 cases treated with quinine during the sweating stage, a relapse occurred in 80%.
6. Of 30 cases to which quinine was given irregularly, a relapse occurred in 80%.
7. Of 120 cases to which quinine was not given at all, there was only one in which no relapse occurred.

The author explains that by “early and systematic treatment” he means quinine given on alternate days in doses of 1.5-2.0 grams per day in three or four doses, with about half an hour’s interval between them, starting the administration three hours before the expected commencement of the fever. But the treatment was suspended after seven days. By “systematic but late treatment” he means the same scale of treatment commenced later in the case. By “daily quinine” he means daily administration of 1-2 grams without reference to the hour of onset of fever, the treatment being suspended after seven to ten days. Apparently in all cases “the cure was recommenced every time that a relapse set in.”

The figures prove fairly clearly the following:

1. The best results (only 13.5% relapses) were obtained with daily doses of quinine.
(2) Good results (only 30.37% relapses) were obtained with the so-called systematic treatment.

(3) Bad results (80.45% relapses) were obtained by the use of quinine late in the paroxysm.

(4) The unfortunate (?) unavoidable? suspension of the treatment after seven to ten days has invalidated most of the author's results regarding the length of the apyrexial period, since, obviously, the parasites would begin to multiply again from the moment that the quinine was stopped and would produce another attack when, a week or so later, they had multiplied sufficiently to do so. It is true that he says in his summary that "though the treatment is prolonged beyond the seven days the relapse occurs all the same;" but this was done apparently only in twenty cases altogether (so far as I can follow the intricacies of the paper), and, as everyone in practice knows, to order a medicine is one thing, to get it taken is another.

With regard to quartan fever there is nothing to add. With regard to malignant fever the author is very emphatic on the point that relapses occur between the fifth and twenty-first days of apyrexia, in spite of energetic quinine treatment; for example, in the case of 90 work-people discharged from hospital after temporary cure, and 792 patients kept in hospital for thirty days, all the former and all except 24 of the latter relapsed. All that the author is able to admit is that the relapses occurred sooner in those discharged from hospital than in those retained there. Unfortunately, he is quite vague as to the continuity of the treatment. In one place he says that "this of course, occurred in patients who had continued the quinine treatment in doses of 1.5 grams per day," and in another place that this had been done "even after the cessation of the febrile attacks," but I do not clearly gather that the treatment had been sufficient and continuous through.
out. Obviously the whole investigation, meritorious as it was, has lost much of its value owing to the uncertainty introduced by the discontinuous methods of quinine administration employed. Regarding relapses after "long intervals" the same element of doubt exists. I suppose that as long as a single sporid remains alive in the blood, the parasites may again reach the pyrogenous limit after a sufficient interval, if the drug is discontinued or continued in insufficient doses. A very careful enquiry is demanded before we can admit with the author that quinine has no effect on the occurrence of such relapses.

Subsequently A. Carducci [1905] made a similar analysis of 50-60 cases at Rome. He infers that relapses at short intervals occur from the 6th to 9th days of apyrexia, mostly on the 7th day, but that in quartan and tertian a relapse is often passed over. He recommends 1 gram of quinine on the 1st, 2nd, 5th, 6th, 8th, 13th, 15th days of apyrexia, and 1.5 gram on the 7th and 14th days in order to check this weekly return, and so on for months and months. With this medication he was able to prevent relapses in most of his cases, but remarks that they recurred if the quinine was discontinued.

On the whole, after studying this and much other literature, I think that there is probably no special periodicity in relapses—that the periodicity noted by some observers was probably due rather to their own periodic methods of medication than to any other cause. If marked periodicity in relapses exists, it should have been widely observed long before now amongst the immense number of cases occurring in military practice—it would certainly have been observed by the military as well as by the medical officers. But I can find few notes to this effect, and certainly remember nothing of the kind in my own practice. As stated in section 20 (6) I am at present inclined to think that relapses occur after quite "irregular intervals, determined by secondary causes or insufficient treatment, rather
than by any inherent property of the parasites; but that there may be some tendency to periodical failure of the germicidal powers (section 65).

Regarding the reputed failure of quinine to prevent relapses, I again remain dissatisfied with the evidence. It appears to me to be merely a question of sufficiency and continuity of treatment.

On the other hand, there appears to be a large mass of evidence in favour of Torri's law that quinine should be administered two or three hours before the commencement of the paroxysm, if this can be determined.

Many authors—Laveran, Koch, Manson, Ziemann, Carducci and others—have suggested various systems of discontinuous dosage, such as the administration of large doses once a week, or twice a week, or every four days, or for two consecutive days every week, or every seven days after the first day of apyrexia, and so on. Owing to the temporary retention of the drug in the blood there is difficulty in understanding the rationale of such proposals. Moreover, a large dose every few days is much more distressing to the patient than a smaller dose every day, and, for this very reason, is apt to be neglected or postponed by him. There appear to be no evidence that the plasmodia become habituated to quinine as trypanosomes do to atoxyl. Personally, therefore, I prefer the continuous method; that is, a dose at least once a day. It seems to have given the best results in Caccini's cases, and is recommended by Celli. We should here distinguish carefully between what may be called medical and hygienic therapeutics. The former is the therapeutics of the physician at the bedside; the latter, that which is to be recommended to the general public—who are, in fact, called upon to treat themselves. Refinements in medication which are possible in the former case are not possible in the latter one, and therefore the simplest possible rule is the one which is to be preferred for hygienic therapeutics* (section 36).
Regarding the duration of treatment required to exterminate the parasites, we have no complete data. The case of T. Manson, who was infected in London in 1900 and was treated for three months, relapsed after nine months. In India the after-treatment of the European troops is continued for six weeks after discharge from hospital, resulting in a considerable reduction in the number of admissions. Thus out of ninety primary cases in two stations there were only seven relapses (Annual Report of Sanitary Commissioner, 1907, p. 11). Teaching on this point differs largely, but I have always given four months as the minimum period, and doubt whether even this is quite sufficient. No harm is done if the patient continues some quinine for six months.

With regard to the different preparations of quinine, much more strict work by enumerative methods on the effect of the various salts on the parasites is required. Estimations of the amounts excreted in the urine and so on give but partial information on the germicidal action—which is the point of importance.

The more soluble salts—bichloride, biphysalate, hydrobromide—are most easily absorbed, and appear most quickly in the urine.

The less soluble salts—sulphate, citrate, tannate, quinina—

are absorbed much more slowly, but, finally, in just as much quantity.

Exact enumerative experiments are therefore required to decide which of these groups of salts have the most germicidal action.

Much has been said recently in favour of the tannate, e.g. by Nussell [1907] and Diederick [1909]. It seems to be slowly but largely absorbed; it remains in the blood; it is inexpensive, nearly tasteless and very suitable for prophylactic use in children (section 36).

Methylene Blue was suggested for malarial by Gottmann.
and Ehrlich (1891), and has been studied by Thayer (1892), De Blas (1905), Wood (1905), Ruge (1906) and others, and various Greek observers. The general conclusion is that it does reduce the sporids to some extent, but not as well as quinine. The investigations must be revised and extended.

The methylblue must be pure, and should be given in coated pills or capsules up to 1 gram or more a day; the atoxyl may be given by injection up to 0.2 grams twice a week. These and other drugs are not yet of importance for preventive purposes.

24. Summary. The doctrine of the parasite invasion given above may be summarized as follows:

The infecting Anopheles probably injects at a single feeding from a few to several thousand protozoa of one or more species of Plasmodium.

Many of the injected protozoa probably perish; but the survivors enter haematos and begin to multiply at an average rate depending upon their species and, possibly, certain other factors.

When the number of parasites reaches something like 50 per cent. of blood the patient begins for the first time to have definite symptoms of illness.

About the same time some kind of germicidal power which opposes the invasion begins to come into play, and tends, in the great majority of cases, to limit the number of parasites below a fatal number.

At the same time some increasing antitoxic power tends to reduce their effect upon the host.

The further history of the invasion is probably that of a constant struggle between the parasites and the germicidal power, tending, in the great majority of the cases, to the final victory of the latter.

In untreated or non-immune cases, this struggle generally
produces a long series of relapses, which tend to be precipitated by many secondary influences acting on the host.

Finally, after this series of rallies and relapses the patient appears often to reach a stage of partial or complete immunity. Possibly, if reinfection does not take place, something like half the cases tend to recover spontaneously every three months.

The effect of reinfections upon the severity & duration of the case has not been estimated.

The case may be cut short at any time by death, spontaneous recovery, or quinine.

There is no reason why we should suppose that the infection is maintained by encystment or parthenogenesis or other special arrangements of the parasites, and the existence of such phenomena has not been proved.

This doctrine can scarcely be verified by the continuous study of entire cases, and is therefore based rather on the comparison of different periods in the history of many different cases, and on reasoning from numerous data.

The careful student of the literature of the pathology of malaria will be struck by the immense amount of admirable work done on the subject. Ideas of number and quantity, however, are often completely disregarded—a common fault of biological work—with the result that many of the secondary theories and explanations will require to be examined over again by more laborious, enumerative and quantitative methods.

I have held it, in the absence of a better doctrine, since 1869, and have always taught it in my lectures and publications.
25. Is the infection caused otherwise than by Anophelines.—
Having considered the parasitic invasion of the individual, we must next examine that of the community.

It was shown in sections 16 and 17 that infection is produced by the bite of certain mosquitoes; but after proof of this was obtained, several capable students of malaria expressed a doubt as to whether this is the only route of infection. We can scarcely wonder, then, if the general public sometimes have similar doubts, and the Health Officer must be always prepared to discuss the matter fully in public. The following questions are easily answered.—

(1). Do mosquitoes exist where there is no malaria?—They do; but this has no application to the subject, as only certain species carry malaria.

(2). Does malarial fever occur where there are no mosquitoes?—Very frequently; as on board ship in mid-ocean, on high mountains, or in Britain in the middle of winter; but such cases are always relapses.

(3). Do Anophelines exist where there is no endemic malaria?—In many places, as in Britain, but the presence of infected persons, as well as of carriers, is required, and, moreover, both must be in sufficient numbers (section 28).

(4). Does endemic malaria occur where there are no Anophelines?—No case of this has yet been established. So far as we know, Anophelines exist in all warm countries, and in most temperate climates during the summer.
But the Anophelines are often difficult to find. Thus, I had been working on the mosquito theory of malaria for two years before I noticed this group of gnats. Dugan (1897) said that there were few mosquitoes in Freetown, Sierra Leone, but we found numbers three years later. In 1900 I observed one flying about in a new house at Fadua, Lagos, West Africa; but five or six, mostly Anophelines, were captured two nights in succession within an old mosquito-net with holes in it, in which a servant slept. If so many had been able to enter through the holes during the night, how many through new were observed must have been flying about free? They abounded in Britain, though the general public scarcely ever noticed them. Before the presence of Anophelines in any locality can be denied, a trained observer must be employed to search for them. Many workers have made similar notes on this point.

It does not follow because the insects are scarce in a locality at the moment when we visit it, that they do not abound at some other season.

(4). Is it possible to become infected in uninhabited localities? Some people, such as several sportsmen and travellers I have met, have stated that they acquired malaria in such places. One told me that he had frequently been attacked a few hours after entering a certain big-game district. We ask in reply (a) what about the incubation period; (b) whether the traveller was unaccompanied by servants; and (c) whether he had travelled in a balloon? We must obviously pass through many inhabited places, where the risks of infection may be great, before reaching the wilderness; we must have servants and carriers with us; and we may indeed have had the parasites in our own blood, without knowing it.

(6). If mosquitoes become infected from men and not from mosquitoes how and when did the process first commence? This question is always asked by the most intelligent person present; and I only wish that we knew the answer. It is concerned
with the whole subject of the evolution of metazoon parasites. Leckart supposes, of course, that they were once free living organisms, which acquired the habit of living first in one host and then, for greater security during the necessary period of migration, in another; and Guerin and A. J. Chabert [1892] have tried to fit this hypothesis to the case of malaria. But there are certain grave difficulties, and for the present it is sufficient to note that we must be satisfied with the facts as we find them.

It has been absolutely proved that malaria does not come from the soil?—It is always very difficult to prove a negative hypothesis of this kind. We never know what surprises Nature does not keep in store for us; we are not omniscient, and wonderful things happen. But the fact that we cannot prove that malaria does not come from the soil is no proof of the hypothesis that it does do so. We are not sure that elephants do not exist in the moon, but our ignorance here does not prove that they do exist there. Malaria may just possibly rise from the soil; but there is no evidence at all that it does so. In my experience, those who argue in favour of this speculation nearly always confound relapses with original infections. Thus, we occasionally meet with cases which are not easy to explain on the mosquito theory, but I have never met one which could not possibly be explained by it.

On the other hand, there are many strong, very strong, arguments against the idea that malaria is bred directly in the soil or in the marsh. In the first place, all experiments to infect men with air or water brought from malarious localities have failed (section 17). Secondly, if malaria were due to any particular kind of soil under certain conditions (as had been supposed), it should always be present where that soil and those conditions exist. But we know that actually it comes and goes. For example, it came to Mauritius in 1866, and to Réunion in 1867; it is still absent from Seychelles and Rodrigues, though favourable conditions for it exist in those
islands, and it has disappeared from Great Britain. But the
soil and the climate of these areas have not changed. Thirdly,
if the poison is diffused in the air it ought to affect every one
within a considerable area round the generating centre, but
as a rule the disease is limited to the immediate vicinity of
the marsh. Fourthly, the telluric miasm ought to attack
especially those who are engaged in digging; but we have never
observed that cultivators and gardeners suffer much more than
their neighbours; while, as a matter of fact, it is generally
the children and even the infants who suffer the most.
Lastly, the idea that the parasites can live in soil, water, and air, as
well as in men and mosquitoes, is extremely improbable in the
light of our general knowledge of parasites.

The last is probably the clinching argument. Living
organisms do not possess independent properties, but accord
more or less in their structure, capacities, habits and life-history
with other organisms. We are cognizant of thousands of
parasites of men, animals and plants; and what we know of
the parasites of malaria shows that they are not markedly
exceptional. In fact they belong to a class of parasites which
infect two hosts, one of which feeds on the other—e.g., for
instance, parasites of the deer and the tiger, the mouse and
the cat, the ox and man, the ox and the cattle tick, and now
man and mosquitoes. The general law is, therefore, satisfied
by the known life-history of malaria. We have no reason to
expect another life-history for the malaria parasites in soil,
water or air, any more than for the other parasites. Then
again, every animal possesses only the limited powers which
have been given to it by the evolution of ages, and for which
it has acquired definite organs and habits of life. The mole
burrows, the fish swims, the bird flies, the parasite occupies
the higher animal or plant. But if this telluric hypothesis is
sound, what remarkable animals must these parasites of malaria
be! They already possess a structure wonderfully adapted
for their life in men and also in mosquitoes, but we must now
expect that they are also able to burrow like the mole, swim like the fish, and fly like the bird! To do all these things they must have the suitable organs; and not only this, but they in their sports must be protected against heat and cold and hosts of enemies in sea, water and air. If all this were true we should have to put the parasites of malaria in a special class by themselves, apart from the rest of creation. These parasites have now led pathologists and parasitologists (who can perhaps appreciate their weight better than others) to abandon the helminth hypothesis as a likely one. There is no evidence in favour of it, and there are very strong arguments against it. The true theorem is obvious. The connection between malaria and the marsh, so long known to suffering humanity, is now fully explained by the fact that the Anophelines breed in the marsh. There is no necessity to believe that the germs also breed in the marsh. Malaria comes from the marsh, not because the germs of the disease come from it, but because the carriers of the germs do so. It is the same thing in the soul. The ancient theory was quite right. Malaria is caused by a marsh miasm. The Anophelines themselves, the mosquitoes, are the marsh miasm.

94. Do other insects besides Anophelines carry malaria?—First we should note that not all, but only certain species of Anophelines carry it, and that according to some, only certain varieties of some of these species are effective. As a fairly general rule, animal parasites are very particular in their choice of hosts. Thus no one has succeeded in infecting animals with human malaria, and the probability is that it will not exist in many kinds of mosquitoes. Between 1895 and 1897 I failed entirely in infecting several species of Culex and Hygromia, though I made experiments on hundreds of the insects; and these results were confirmed by the梵ian observers, by Stephens and Christophers, and by many others. But, nevertheless, such negative results are never absolutely conclusive unless enormous numbers of experiments are made,
because it is always possible that some condition, such as of temperature or humidity, may have been overlooked, or that the proper species or variety may not have been used. But there is a strong argument against mosquitoes in general being concerned, namely, that from the earliest times malaria has been known to be connected with marshes, while many mosquitoes, such as Aedes and Stomoxys, do not breed in marshes as a rule, but in petty collections of water round houses. If these carry malaria, then malaria should abound everywhere, especially in towns, and not so exclusively near marshes. A good contrast is found in the case of yellow fever, which does abound in towns and not particularly near marshes—(for the simple reason that it is carried by Simulium). On the whole, then, though we cannot say definitely that malaria is not carried by other hosts than Anophelines, yet there are strong reasons for this opinion. At all events we are fairly certain that most insects which carry it must be marsh-born, like the Anophelines; so that the principal preventive measure of drainage is not seriously affected by the question.

(c) Do the human parasites live also in animals?—In 1895 in Calcutta, my servant, Mohamed Bux, became suddenly infected with malaria, which he thought he had acquired while collecting mosquitos fed on infected birds. At present, however, no one thinks that the parasites of men and of animals are the same. The attempts of Di Mattei and others to infect birds from men were all negative.

(d) Do the parasites enter the eggs and larvae of mosquitos?—In 1898 also, I thought that the protospores of P. falciparum might enter the eggs of the carrying mosquitoes, but all my attempts to find them there were failures. More recently Schaudinn [1904] has sought to revive this hypothesis; but he gave no proof of it. Such a thing happens, however, with Trypanosomes in ticks, and has been suggested as possible in the case of yellow fever. If it happens in malaria, the parasites would be passed on, not only from mosquito to man, but also...
from mosquitoes to mosquitoes. I have had no opportunities for examining the subject further, but may add that my studies of the point in 1898 were very useful. We should not accept the suggestion, even tentatively, without much better evidence.

25. Some Definitions.—We are therefore almost sure that infection with the parasites of malaria occurs in nature only through the bites of mosquitoes — probably only of certain species of Anopheles. But this statement is not nearly sufficient for all the purposes of prevention, and we must discuss the subject in much greater detail. Why does the disease vary in amount from place to place, or even in the same place from season to season, or year to year? Why does it disappear from some countries and appear in others? The whole subject of the prevention of malaria is based upon a rational study of these questions, and the reader who is called upon to undertake such work must exert himself to consider them thoroughly. We must first have clear ideas upon the following points:—

(1) The cases of malarial fever which occur within a given locality belong, of course, to two classes, the indigenous ones and the imported ones. The first are those who were infected within the locality; the latter, those who were infected outside it, but who, after immigration, remain infected within it. The latter class may be very numerous in military stations, hill stations, and sanatoria. But they also abound in many villages of which the inhabitants are given to working elsewhere during the malarious months; and among bands of immigrant workmen. On the other hand, in small towns and villages with fixed populations most of the cases are apt to be indigenous ones. It is often difficult to determine the proportion of such cases because many of the imported cases may be reinfected within the area.
of observation, while many of the indigenous cases may have emigrated since infection.

(2) By the malaria rate of a locality I mean the percentage of persons who contain plasmodia at some given moment. We may divide this into the indigenous malaria rate and the imported malaria rate. The former may also be called the malarial endemicity of the place.

(3) By the malaria index, or endemic index, of a locality I mean the percentage of persons in whom any evidence of malarial infection was found at some given moment. It will be clear from Chapter IV that such evidence cannot generally be found in all the cases of malaria in a locality—many may contain plasmodia without showing them or any objective symptoms of them. Conversely, many people may show evidence of past infection, such as enlarged spleen, without containing plasmodia at the moment. We may divide the endemic (or malaria) index into the adult, the juvenile and the infantile endemic index.

(4) By the daily, monthly or annual inoculation rate of a locality I mean the percentage of persons who were inoculated or reinoculated by mosquitoes during the day, month or year referred to.

(5) When we talk of the amount of malarial fever in a locality we generally refer to the total malaria rate in it. When we talk of the amount of malaria in it we generally mean its indigenous malaria rate. When we say that a place or a season is very malarious, we mean that the inoculation rate is very high for that place or season.

The term "endemic index" was first used by Stephens and P. Christopher in 1845.
(6) By the **malaria case mortality** we mean, of course, the proportion of infected persons who die of the disease.

(7) By the **malaria mortality** we mean the proportion of the total population who die of the disease.

(8) I use the word **ratio** to denote a proportion, and the symbol **%** to denote a percentage. The latter is obtained by multiplying the former by one hundred.

27. Conditions required for the Production of New Infections in a Locality.—From what has been written already it will appear that new infections can occur in a locality only if all the following conditions exist:

1. That a person whose blood contains a sufficient number of *gametids* (sexual forms) is living in or near the locality.

2. That an *Anopheline* capable of carrying the parasites sucks enough of that person's blood.

3. That this *Anopheline* lives for a week or more afterwards under suitable conditions—long enough to allow the parasites to mature in it.

4. That it next succeeds in biting another person who is not immune against the disease or is not protected by quinine.

To these we must now add the following principle:

5. That few or no new infections will occur in a community unless the persons with gametids in their blood and the carrying *Anopheles* are sufficiently numerous.

This last proposition is the basis of the public prevention of malaria. Although tacitly admitted, it is never properly discussed in the monographs, and the reader must therefore examine it here in detail and as precisely as possible.

Let us suppose that we have to do with a population of 1,000 people living over an area in which indigenous malaria does not exist; and suppose that one of these people is an
imported case with suitable malaria in his blood. Next, suppose that a single suitable Anopheline is liberated within the area. What are the chances that this insect will ever cause a new infection?

First, we observe that not every mosquito can succeed in biting human beings at all; suppose that the chances are 5 to 1 against this happening. Next, we observe that as there is only one infected person among the 1,000 people in the place, and as the particular Anopheline liberated in the area may bite any one of these people, the chances are 999 to 1 against its happening to bite the patient, even if it succeeds in biting at all. That is, altogether, the chances against its biting the patient are 999,999 to 1. But suppose that this has happened. It must now live for a week or more afterwards, and not all mosquitoes live so long. Suppose that the chances are 2 to 1 against this particular Anopheline living long enough to mature the parasites in it—so that the chances are 11,999 to 1 against the Anopheline reaching the infective stage. But it must now bite a second person. Suppose that the chances against this are, again, 3 to 1. Thus the total chances against this Anopheline inoculating another person will be something like 48,000 to 1. In other words, if instead of liberating a single Anopheline within the area of observation we had liberated 48, this would have a chance of only one in 48,000 of causing infection, and would also live long enough to become infective and to bite a second person. Of course, by bad luck, as to speak, a larger proportion of the insects might succeed in this; but, on the other hand, by good luck, none at all might succeed. Such calculations, though obviously based on conjectural data, yet suffice to show the absurdity of supposing that the presence of a few Anophelines must cause an epidemic of malaria.

Or we may consider the subject as follows. Suppose that 48 Anophelines on the average live near the infected person. Then, if the conjectural data are sound, 1/4 of these, or 12,
will succeed in biting him; 1/3 of these, or 4, will live for a week or more; and only 1/4 of these, or 1, will succeed in biting another person. If 48 Anophelines live near each one of the 999 healthy people, there will be 47,952 Anophelines which can bite only healthy people, and which cannot therefore cause new infections. Thus, on the average, only 1 out of 48,000 Anophelines will succeed in infecting another individual.

If instead of only one person with gametids in the blood there are 2, 3, 4 or more in the locality, then if there are 48 Anophelines on the average to each person, 2, 3, 4 or more new infections may be caused. Thus, obviously, the number of new infections in a locality, that is, the multiplication rate, depends on two factors (other things being equal), namely, the number of Anophelines and the number of previously infected persons in the locality.

It is useful to put these thoughts into simple symbolic language. Let \( p \) denote the human population of the locality; \( m \) the number of malaria-infected persons; and \( i \) the number of those with gametids in the blood. Here \( m \) and \( i \) are fractions, since \( mp \) is less than \( p \) and \( imp \) less than \( mp \). Also \( m \) may vary from 0 to 1, since the number of infected persons may be anything from zero to the whole population. The fraction \( i \), being the proportion of infected persons with gametids in their blood at the moment of enquiry, may be put at 1/4 or may be much less.

Again, let \( a \) denote the number of Anophelines (of some malaria-bearing species) to each human being—so that \( ap \) denotes the total number of Anophelines in the locality, and \( aimp \) the number of Anophelines compared with the number of persons with gametids. Let \( b \) be the proportion of these \( (say \ 1/4) \) which succeed in biting; \( s \) the proportion \( (say \ 1/3) \) which succeed in maturing the parasites; and \( b \) the proportion which succeed in biting another person. Thus, \( i b s \) gives the number of Anophelines which succeed in infecting persons.
We have assumed that \( b = 1.4, s = 1.3, i = 1.4 \), so that if each of these bites a different person, we shall have:

\[
\text{No. of inoculations} = \frac{\text{inoculation rate}}{2} \times \text{population of area} \times \frac{1}{2}
\]

Inoculation rate per cent. = \( \frac{\text{inoculation rate}}{100} \times \frac{1}{2} \approx \text{about } \frac{1}{2} \%
\]

That is to say, the inoculation rate per 100 of population equals about half the malaria ratio (m) multiplied by the mosquito ratio (r).

For example, in a village containing 1,250 people, 750 infected people, and 3,000 Anophelines, \( p = 1.25 \), \( m = 0.6 \), \( r = 2.4 \); and we calculate roughly that the number of inoculations, and also of inoculations, will be about 92. The inoculation rate per cent. will be about \( \frac{92}{1,250 \times 0.6} \approx 0.72 \); that is, the chances of being inoculated in the village will be as 72 is to 10,000.

Or suppose that in another village half the people are infected, and there are about twenty Anophelines to each person. Then the chances of becoming infected there will be about 5 per cent.

Such calculations may appear far-fetched to many, but they are useful, not so much for the numerical estimates yielded by them, but because they give more precision to our ideas, and a guide for future investigations.

### 22. Laws which Regulate the Amount of Malaria in a Locality

The number of infecting mosquitoes which succeed in biting again is \( b \sigma m p \). If all of these bite different people, and all these people are healthy, and all become infected, this expression will also denote the number of new infections occurring in the locality. But, of course, the infecting mosquitoes may often happen to bite on the second occasion, i.e., healthy persons, but persons already infected, especially if the proportion of the latter is large.

If as before, \( m p \) denotes the number of persons already infected at the beginning of the enquiry, then \( b \sigma m p + \sigma (1 - m) p \) denotes the number of healthy people. Hence by proportion...
the number of infecting mosquitoes which bite healthy persons (on the second biting) will be \( x \), where

\[ x = \frac{b}{b + s} \left[ \frac{1}{p} - p \right] \]

and if each bites a different person and each person becomes infected, the same expression will denote the number of new infections which occur in the locality—that is, will denote the addition to the number of malaria cases there.

But this is not the whole change which may occur. While during the period of observation, new infections are being produced, it may happen that some of the old cases may have recovered. The number of those old cases was originally \( n_s \); let \( n_r \) denote the number of those who have recovered during the period of observation—that is, that \( r \) is a fraction. Hence the whole number of cases in the locality will have increased or decreased at the end of the period of observation, according to whether \( \frac{n_s}{n_r} (1-r) \) is greater or less than \( n_r \), the number of recoveries. Thus neglecting common factors, the change depends upon whether \( \frac{n_s}{n_r} (1-r) \) is greater or less than \( r \).

Suppose that no change occurs—that the recoveries exactly equal the new infections. Then

\[ \frac{n_s}{n_r} (1-r) = r \]

From this equation we can calculate the values of \( n_s \) and \( n_r \) when the amount of malaria in the locality remains constant—that is, if we know the values of \( b, s, i, \) and \( r \).

Suppose that the period of observation is one month. Now, in section 21, I estimated roughly that only about half the cases of malaria remain infected after three months. If this ratio holds for smaller periods, we may suppose that the ratio of people who remain infected after only one month will be given by the cube root of \( \frac{1}{2} \)—that is, by \( 0.7937 \); so that the proportion of those who recover in one month will be \( 1 - 0.7937 \). That is, we may write \( r = 0.2063 \). Let us take the values of \( b, s, i \) as suggested in the previous section—namely, that \( b = 1, s = 0.5, \) and \( i = 0.2 \).
Hence the new infections will equal the recoveries if
\( \frac{m}{1 - m} = \frac{0.2 \times 0.063}{0.063} = 0.2 \),
and the malaria will increase or diminish in the locality according to whether \( \frac{m}{1 - m} \) is greater or less than 0.2. Thus, if \( m \), the original malaria rate, is very small, the malaria will not increase unless \( m \), the monthly number of Anophelines per head of human population, is greater than 0.2. On the other hand, if \( m \) is a larger fraction, say 1.2, the malaria will not increase unless \( m \) is greater than \( 0.2 \). If \( m \) is still larger, say 3.4, the malaria will not increase unless \( m \) is greater than 0.2. This suggests that the malaria rate is not likely to increase indefinitely unless the number of mosquitoes is enormous. On the other hand, if the number of Anophelines is below the figure given by the equation, the malaria rate ought to begin to fall, because the new infections can no longer keep pace with the recoveries.

It should be noted that by the number of Anophelines we here mean the number of different Anophelines which may bite each person during a whole month, and not the insects which may be, so to speak, allotted to each person at any one moment. We say one month because this is the period we have selected for observation—the period during which we suppose that \( m \) or a third of the cases recover. If we had selected one week for the period of observation, the proportion of recoveries would, of course, be lower (about 0.0567), and the number of different Anophelines to each person, required to compensate for the recoveries during the week, would be correspondingly less (as shown by the equation).

Now, what will happen if the malaria rate, instead of remaining constant, increases or decreases? On the one hand, will it increase until everyone becomes infected; or, on the other hand, will it decrease until it vanishes?

We have supposed that \( m \) denotes the number of cases at the beginning of the inquiry, which lasts, let us say, for a month. Let \( m_1, m_2, m_3, \ldots \) denote the number of cases
at the end of 1, 2, 3, . . . months respectively. Then if the
other figures remain constant, we have,
\[
\begin{align*}
\frac{\text{mo. cases} + \text{new infection} - \text{recovery}}{\text{mo. dep.}} &= \frac{n}{(1 - \alpha) (1 - \beta) m - \text{rec.}}
\end{align*}
\]
and as the same process repeats itself month after month we continue to have,
\[
\begin{align*}
\text{mo. cases} &= \text{mo. cases} \times \frac{n}{(1 - \alpha) (1 - \beta) m - \text{rec.}} + \text{new infection} - \text{recovery} \\
\text{mo. recovery} &= \text{mo. recovery} \times \frac{n}{(1 - \alpha) (1 - \beta) m - \text{rec.}} + \text{new infection} - \text{recovery}
\end{align*}
\]
and so on. We can calculate \( n, p \) from the first equation. Substituting its value in the second equation we calculate \( w, r \); and substituting this in the third equation we calculate \( m \); and so on indefinitely.

If \( r + \beta = 0.00 \) the value of the art term of the series \( n, p, m, r, w, p, m, r, p, m \) may be written
\[
\begin{align*}
\text{mo. cases} &= \frac{n}{(1 - \alpha) (1 - \beta) m - \text{rec.}} \\
\text{mo. recovery} &= \frac{n}{(1 - \alpha) (1 - \beta) m - \text{rec.}} \\
\text{mo. death} &= \frac{n}{(1 - \alpha) (1 - \beta) m - \text{rec.}}
\end{align*}
\]
Let us now consider for example the case of a village containing 2000 people of whom half are infected at the beginning of the inquiry. By equation (10) of this section, and also by this equation, if the number of different Anopheles per person during one month is \( 0 \), the malaria will neither increase nor decrease, so that \( n, p \) will always be the same as \( n, p \), namely, \( n, p \). But if \( p \) is greater or less than this, the malaria will increase or decrease accordingly.

(11) First suppose that there are 100 different Anopheles per person during a month—so that the malaria should increase. Thus we calculate,
\[
\begin{align*}
\text{mo. cases} &= \frac{2000 + 100}{2000 (0.5) (0.5) (500)} = 550 \\
\text{mo. death} &= \frac{2000 + 100}{2000 (0.5) (0.5) (500)} = 549.5
\end{align*}
\]
Proceeding in this way we find that the number of cases should increase every month as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>500</td>
</tr>
<tr>
<td>1</td>
<td>549.5</td>
</tr>
<tr>
<td>2</td>
<td>598</td>
</tr>
<tr>
<td>3</td>
<td>647</td>
</tr>
<tr>
<td>4</td>
<td>694</td>
</tr>
<tr>
<td>5</td>
<td>740</td>
</tr>
<tr>
<td>6</td>
<td>786</td>
</tr>
</tbody>
</table>

Increase of Cases with 100 Anopheles
160 MALARIA IN THE COMMUNITY [SECT.

But how do we reach the last figure? As we calculate the number of cases month after month we observe that they always increase, but by a constantly decreasing increment. Finally, this increment becomes very small, so that the number of cases approaches a fixed limit. It is easy to calculate this limit mathematically (as will be done presently), but we can also calculate it very simply as follows.

If the number of cases does ever arrive at a fixed limit, so that it no longer increases, then equation (1) of this section must hold; that is, the number of cases and the number of mosquitoes will be exactly balanced according to the formula

\[ n = \frac{m - \log_{10} n}{\log_{10} \frac{40}{10}}. \]

From this we have, when the exact balance is reached,

\[ n = 1 - \frac{\log_{10} n}{\log_{10} \frac{40}{10}}. \]

Here, \( n \approx 1000 \); so that finally \( n = 1 - \frac{\log_{10} n}{\log_{10} \frac{40}{10}} \), which, when multiplied by the population (1000), gives 600 cases as the final limit.

Next, suppose that there are only 60 mosquitoes per person. Then we calculate as before,

<table>
<thead>
<tr>
<th>Months</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>300</td>
<td>475</td>
<td>661</td>
<td>857</td>
<td>1044</td>
<td>1201</td>
<td>1216</td>
<td>1216</td>
</tr>
</tbody>
</table>

The final result is obtained as before from equation (6). Here, although the malaria ratio diminishes rapidly at first, it never disappears altogether, but ultimately stands at 0.3 of the population.

Next, suppose that there are 40 mosquitoes per person.

<table>
<thead>
<tr>
<th>Months</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>300</td>
<td>450</td>
<td>525</td>
<td>576</td>
<td>618</td>
<td>640</td>
<td>640</td>
</tr>
</tbody>
</table>

Here the fall is quicker and the malaria finally vanishes, because \( m = 1 - \frac{\log_{10} n}{\log_{10} \frac{40}{10}} \), but very many months will elapse before this result is approached.
THE LIMIT OF MALARIA

(4) We also have

<table>
<thead>
<tr>
<th>Months</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>...</th>
<th>finally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>300</td>
<td>300</td>
<td>333</td>
<td>333</td>
<td>333</td>
<td>...</td>
<td>0</td>
</tr>
</tbody>
</table>

(5) Cases of Malaria with no Anophelines.

<table>
<thead>
<tr>
<th>Months</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>...</th>
<th>finally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>300</td>
<td>300</td>
<td>333</td>
<td>333</td>
<td>333</td>
<td>...</td>
<td>0</td>
</tr>
</tbody>
</table>

Thus the percentage of only a small number of anophelines does not affect the result very much. In fact we can see this from the form of the equation (4), namely,

\[
mP = \frac{m_0 P}{1 + \frac{m_0 P}{m_0 + 1}} \approx \frac{m_0 P}{m_0 + 1}
\]

because \( m_0 \) is always a fraction, and \( m \) must therefore be a considerable number if it is to have any marked effect compared with the first term \( m_0 \).

Returning now to the subject of the limit mentioned in example (1). It is known in mathematics that if a series such as \( m_0 P, m_1 P, m_2 P, \ldots \) here considered tends to a limit, that limit can often be easily found. Let \( m \) denote the limit—that is, \( m = m_0 \) when \( n \), the number of terms, is indefinitely increased. In other words, \( m \) is the malaria ratio which is finally arrived at after the lapse of many months.

Now we had in equation (4),

\[
mP = \frac{1 + BP}{1 + \frac{1 + BP}{m_0 P}}
\]

By the mathematical rule referred to, the value of \( m_0 P \) or \( mP \) can be easily found, when \( m \) is large, by solving the equation

\[
mP = \frac{1 + BP}{1 + \frac{1 + BP}{m_0 P}} m_0 P
\]

that is,

\[
m = \frac{m_0 P}{1 + \frac{m_0 P}{m_0 + 1}}
\]

If \( m_0 = 0.2 \) and \( P = 100 \), this gives \( m = 0.02 \), which is the same as equations (2) and (3), which have already been used to find the limit shown in example (1). There we calculated the limit by another line of reasoning, but now we see that it can be obtained also by the ordinary mathematical rule. (This rule is that if \( f(x) \) is a repeated function of \( x \), its value when \( x \)
is indefinitely large will often be given by the roots of the
equation \( r = q t \).

The reader should make a careful study of these ideas,
and will, I think, have little difficulty in understanding them,
though he may have forgotten most of his mathematics. If
our reasoning has been correct and complete enough, the main
principles involved may be stated as follows:

(I) Whatever the original number of malaria cases in the
locality may have been, the ultimate endemic malaria ratio
will tend to settle down to a fixed figure, dependent on the number
of Anophelines and the other factors—that is, if these factors
remain constant all the time.

(II) If the number of Anophelines is sufficiently high, the
ultimate malaria ratio \( (n) \) will become fixed at
some figure between 0 and 1 (that is, between
0.001 and 1.001). If the number of Anophelines is
sufficiently low (say below 40 per person), the
ultimate malaria rate will tend to zero—that is, the
disease will tend to die out. (In this calculation a
negative malaria ratio, that is, one which is less than
nothing, must be interpreted as meaning zero).

Consider, for example, the case of a village with 1,000
inhabitants and 60 different Anophelines for each person
during one month. If, to begin with, every person starts with
being infected, then the malaria ratio will fall month by month
until it reaches the value \( n = 1 - 0.0001 \); that is, until 333
persons are left infected. And this occurs because there are
not enough Anophelines to maintain the original high rate of
100% infection. But now suppose that with the same number
of people and of Anophelines, the epidemic begins with only
one infected person from outside; the number of Anophelines

\[ \text{infection.}
\]

\[ \text{This is a well-known property of repeated functions. See, for instance, my paper
"A Method of solving Algebraic Equations," Amer., 29th October 1908,
and p. 612.} \]
THE LIMIT OF MALARIA

will now be too large to allow this original low rate of 0.1% infection to continue, and the rate will consequently rise until the value $m = 1.40$ is reached, giving 333 infected persons, i.e. the ultimate result will be the same—the number of cases will be 333, and will continue at that figure so long as all the factors remain the same. Thus, whether every one, or only one person, is infected to start with, the ultimate result will be the same—333 infected persons, giving 333 cases, and will continue at that figure so long as all the factors remain the same. That is, an exact balance between the number of cases and the number of mosquitoes will be arrived at. Many months may, however, elapse before this happens.

Suppose that all the factors $K_1, K_2, K_3$ remain the same. Then, if any of them is temporarily altered, a corresponding change will be made in the rate of increase or decrease; but after the temporary disturbance has ceased, things will again tend to return to the normal state—just as water always seeks to find its own level. Thus, if the recovery rate $r$ is increased by a temporary administration of quinine, or the number of mosquitoes $a$ is temporarily diminished by winter or by active “petroleum,” a change for the better will be made, but it will cease soon after the alteration ceases. If, however, the alteration is permanent, then the value of $m$ will, of course, be permanently affected by it.

We have chosen certain assumed values for some of the factors; does this fact invalidate the reasoning? We will examine these values more closely in the next section, but the exact figures do not affect the general law. We have supposed that, in equation (7) $P=P=40$, from which we argued that the ultimate malaria rate will vanish if the number of different mosquitoes to each person is less than about 40 per month. The actual number may be more or less, but the fact that a limit must be reached remains. As I have said, the whole calculation is useful, not so much for its numerical results, but because it gives precision to our ideas.

A more serious objection is that, in framing the fundamental equation (4), we have disregarded certain factors which would modify it. For example, the population will be subject
to constant changes owing to immigration, emigration, births and deaths—all of which operate both on the healthy and on the infected. Thus the birth-rate will give a continuous supply of healthy individuals, while the death-rate will remove many of the infected ones. Also many of the recovered cases, and many of the mosquitoes, may be at least partially immune; gametoids may appear in the blood more during some seasons than during others, and infected mosquitoes may bite many more than one person each; but the introduction of all these factors would give a much more complicated equation than we have need for here. It will still be of the form

\[ P = \text{original cases + new infections - recoveries (or deaths)} \]

and from this we shall still be able to argue that a limit must be reached when the new infections exactly balance the recoveries. We may therefore conclude,

1. That the amount of malaria in a locality tends towards a fixed limit determined by the number of malaria-bearing mosquitoes and by other factors.

2. That if the number of malaria-bearing Anophelines is below a certain figure, that limit will be zero.

It is often thought and said that malaria should exist wherever susceptible Anophelines exist, and that anti-mosquito measures will therefore be useless so long as any of these insects remain. But more careful reasoning will convince us that malaria cannot persist in a community unless the Anophelines are so numerous that the number of new infections compensates for the number of recoveries.

29. Laws which Regulate the Number of Anophelines in a Locality.—We have seen, then, that the amount of malaria in a locality depends (among other factors) upon the number of suitable Anophelines, and upon the proportion of them which succeed in biting human beings, in living long enough to mature the parasites, and in biting human beings again.
We must now study these points in greater detail. Unfortunately, although much entomological work has recently been done on mosquitoes, such important subjects as these have received little attention.

1) The output of mosquitoes from marshes—1 know of no adequate studies on this point. In 1906, in Mauritius, I stretched a mosquito-net over 9 square yards (7.249 square metres), and counted every day the mosquitoes hatched within it. The selected spot (Clairfont Marsh) was covered with rank grass, the ends of which were submerged by an inch or two (2.5-5 cm) of water. It was sheltered by trees, and was an ideal spot for the breeding of *Aedes maculipennis*. Daruty and D'Emestre, 1900 (a *Anopheles* which does not carry malaria). The observations were continued for sixteen days in January—the warm rainy season; and only this kind of mosquito was found. Altogether thirty males and thirty-one females were obtained, giving an average of 0.424 per square yard per day, or 5,062 per 10,000 square metres. Numbers continued to hatch out on the sixteenth day. During the daytime the adults took refuge in the grass, from which it was necessary to expel them. Clairfont Marsh is about 1,400 feet (427 metres) above sea level (section 30 (1)).

This output (about 5,000 mosquitoes per day for 100 yards square of marsh) seems to have been rather large, as when the net was placed in another position the yield was much smaller. Taking twenty days as the average life of an *Anopheles* (conjecture), 100,000 of them should thus be in existence on any one day in the neighbourhood of such a marsh of about 100 yards or metres square.

Of course the output is sure to vary from point to point of a marsh, according to the breeding capacity of different depths of water, etc.; and it will also vary from

1 Nuttall and Shipley found equal numbers of males and females with *A. maculipennis* also (January 1906).
day to day according to the amount of rain, wind and sunshine.

Correct and sufficient observations on these points are much needed. They could be made by the use of small square tents of muslin netting, supported by a central pole, and pegged out with weighted margins over a unit of area (say 1 square yard). We might thus ascertain not only the mosquito-output but the length of the aquatic life of mosquitoes under natural conditions, and other facts. Of course a number of such tents must be used to avoid much error of random sampling.

(a) The average life of the winged insects.—It used to be thought that mosquitoes feed on one occasion, lay their eggs a few days later, and then die. But in 1898, observing that this short period did not suffice to allow the malaria parasites to develop fully in Culex fatigans, I ascertained that these insects could be kept alive in captivity for a month, and possibly much more, by repeated feedings [21st May 1898]; and I obtained the same results with certain Stegomyia and Anophelines. Since then, similar observations have been made on many mosquitoes. Thus Goeldi [1905] kept a female Stegomyia calopus alive for 103 days, and a male one for 72 days. The average life in captivity of 15 females was 53 days, and of 11 males was 50 days. My general experience has been that it is easy to keep various species of Anophelines alive in captivity for two or three weeks, but not so easy to keep them longer. Nuttall and Shipley [1902] kept A. maculipennis for 56 days, and found that the females tend to live longer as winter approaches, possibly in connection with hibernation (Woldert). It has long been known that many mosquitoes hibernate and aestivate. Females appear to live in captivity longer than males. Better experiments with large mosquito-houses, fixed in the open air under natural conditions, should be made.

But such observations do not settle the important question,
SEE THE MEASURING THE OUTLET OF MONTOIS FROM A WAGE-SLAVESHOLD, AVALONI.

BACK OF A STREAM TRAINED FOR IRON TO A RUNNING PONT FOR BOTH IRON WORKING.

FRONTIER.
AVERAGE LIFE OF MOSQUITOS

what is the average life of mosquitoes in nature? In captivity, they doubtless suffer from confinement, but, on the other hand, are preserved from their natural enemies and from heat, wind and weather, which probably destroy immense numbers of them. We should like to know what percentages survive for one, two, three... weeks. Numerous experiments on the point could be performed, but have been neglected. In the meantime, I have always taught the following hypothesis. The average natural life of an animal is likely to exceed that of any parasitic organism which it may contain. The latter have been instructed, so to speak, by the evolution of centuries, as to the length of time they should spend over their development, so as to have the best chance of being propagated to other hosts. Thus Filaria bancrofti requires about three weeks to develop in Culex. Now, if the average life of Culex were less than three weeks, the Filaria would have a much smaller chance of propagation. Doubtless, therefore, the average life of Culex exceeds three weeks or a month. Similarly, plasmodia require about ten days to develop in Anophelines, and I therefore suppose that the average life of these insects reaches about three weeks or more. But this reasoning suggests only the lower limit of average life. Evidently a longer average life would improve the chances of propagation of the parasites. The mosquito death-rate must, of course, vary largely in consequence of many factors, such as season, enemies, local conditions of shelter, etc. On the whole, I think that we shall not be far wrong if we accept our previous estimate that only about one-third of the carrying Anophelines live for ten days—long enough to allow the plasmodia to mature in them.

(3). The proportion of mosquitoes which succeed in biting human beings—With most species only the females, that is, half the number, suck blood at all. When a number of females are liberated all night within a mosquito-net occupied by a man or by birds, only a variable proportion are found next morning to be fed. Numerous observations have been made, 

1 See also section 66.
by myself, among others, which show that the insects are not very hungry for about twenty-four hours after hatching out from the pupa, or immediately after laying their eggs. With species which attack animals (birds, cattle, dogs, etc.), the chances are that the proportion of insects which succeed in biting men varies with the proportion which exists between the number of men and of these animals in the locality. Men must be more difficult to reach than defenceless animals (or children). The richer classes often use mosquito-nets; and poor natives, especially Indians, generally cover themselves from head to foot with a sheet during sleep, besides filling their huts with smoke at night time, and keeping their doors and windows shut (the common habit, even in hot climates). Access to people is easier stoves, with small open windows, must often be difficult to these feeble insects, especially while any breeze is blowing.

I have suggested that possibly a quarter of the Anophelines may succeed in biting human beings once; a third may live for ten days more, and a quarter may succeed in biting again—which is, that only about 1/24 of the females can ever have any chance of carrying malaria. But this applies only to the proportion of mosquitoes in each person in the place, and supposes, moreover, that the human beings are evenly distributed in the locality, and are fairly accessible. In thinly-inhabited places the ratio will probably be much smaller, and in crowded towns, larger. I think that many insects which have failed in procuring a meal during the night may die of starvation (in my experiments on birds a number of dead mosquitoes were generally found in the nets every morning). Numbers of gorged mosquitoes are probably devoured by bats, birds and spiders, or are killed by sufferers. On the whole, then, an average ratio of 1/24 is perhaps too high.

Many observers have studied the proportion of naturally-fed Anophelines which contain plasmodia. In 1899, I found the parasites in 27 out of 109 P. gallinae caught in a military
hospital in Freetown, Sierra Leone, in which one quarter of
the men examined contained them [1900]. Stephens and
Christophers found them in 670 of Anophelines in the same
town [5th April (4) 1900]; in 30i of Africa "as a rule"; and in some villages up to 60i [1903]. Ziemann, A. Flebo,
the Singhis, and many others have found similar rates.
Unfortunately, such observations do not help us much, because
the mosquitoes caught in houses may possibly be only or mostly
those which have already obtained human food, and are waiting
for more.
In the huts of poor natives, and in badly-managed barracks
and hospitals where many unprotected people sleep in the same
room, a single mosquito may often be able to bite several
persons during the one night. In such houses the chances of
infection must be enormously increased, and the practice of
congregate sleeping must be one of the principal causes of
the diffusion of malaria.
(4) The number of Anophelines in and of area.—Nothing
approaching accurate scientific work has been done on this
subject. There are many references in literature to "few
mosquitoes," to "many mosquitoes," to "swarms of mosquitoes,"
to "des centaines de millions de millions," and so on. Theobald
[1901, I, 72] describes having twice seen clouds of male and
female C. quinquefasciatus in the English Fens, darkening the air,
and producing a sound which could at times be heard a quarter
of a mile distant. He says that W. W. Smith records that a train in New Zealand "passed through a wall of mosquitoes
three-quarters of a mile in length, twenty feet high, and eighteen
inches thick," and he mentions dense masses of goats "like
columns of smoke." If there were ten mosquitoes to the cubic
foot in this "wall," there would have been only 1,188,000 insects
in the whole collection—not a large number considering the
possible output (5). Such phenomena merely suggest that
occasional "swarming" occurs with mosquitoes as with other
animals (including man).
Anophelines in houses have been frequently caught and counted, especially by Stephens and Christopher and recent observers in India. The numbers may vary from zero to many hundreds in a single room, especially in thatched huts. They may also vary from house to house, and according to distance from breeding waters. It is impossible to quote any correct averages. I have thought, as a general conjecture, that one Anopheline for each human occupant might be adopted as a kind of standard for comparison, but, of course, near marshes the numbers often rise to 50, 100, or more in each room, or even to each person.

We cannot estimate the number of any species in unit of area by the number caught in houses in that area, unless we know the proportions of that species found inside and outside houses respectively, at the hour of the day when the search is made. As we can never know this proportion exactly, the number of insects caught inside houses is no exact guide to the total number existing within the area of observation.

Different species appear to differ largely as to the amount of time they spend in human habitations. I define domestic mosquitos as those which pass a large part of their lives in houses, such as C. fatigans, S. stephensi, M. quadridens; though even with these species we do not know exactly how many hours they spend indoors and out-of-doors respectively. I define sub-domestic mosquitos as those which enter houses only for the purpose of feeding, and wild mosquitos as those which never enter houses at all\(^1\). Some species, such as A. maculicorsides, are found in verandas of houses, but not commonly in rooms.

The average output, average length of life, and average number per unit of area of any species of mosquitos are correlated quantities which can be ascertained only by the most careful measurements, such as have never yet been attempted (so far as I can ascertain).

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1 Arribabaga and Ficalbi give similar classifications. The latter is based on the habits of the latter.
In the previous section I computed roughly that malaria is not likely to persist in a locality where the pathogenic Anopheles number less than about forty different individuals to each person during a month. It would be very difficult to ascertain anywhere how many different mosquitoes there are to each person, but the attempt should be made. More personal impressions on the point are apt to be very wrong. The victim, surrounded by many mosquitoes, tends to magnify their number from one to ten, and from ten to a hundred. The use of a white muslin hand net, with which his enemies can easily be caught, will disclose the truth. I am inclined to adopt the following standard. The mosquitoes in a room or veranda are numerous if a single person is attacked by more than five at a time, and very numerous if he is attacked by more than ten. There are few houses in the tropics where one is not solicited day and night by two or three mosquitoes.

If we count the number of Anopheles found in a set of houses every day for a number of days, we could obtain the average number to be found in one for each person living in the locality. But we cannot say that all these are different mosquitoes. We may, however, attempt a very rough computation as follows—Suppose that on the average there are 10 Anopheles to each person every day. Then, if all the insects are changed every day—that is, if each insect lives only 24 hours on the average—there should be about 24 x 30 = 700 different insects to each person during a month of 30 days.

If, however, the insects live for 15 days on the average—that is, are changed twice a month—there should be about 24 x 15 = 360 different insects to each person during the month. If the insects live 30 days, there should be only 10 different ones to each person. Thus if $n$ is the average number of mosquitoes found per hour per person, $a$ is the number of different mosquitoes per person during a month of 30 days, and $l$ is the average life of the mosquitoes in days...
we should then have roughly $n = \pi \times 30^2$. If $\pi = 27$ and $l = 20$,
then $a = 40$, the number roughly computed as the malaria-
maintaining limit.¹

To sum up — if we think over these points carefully (and
this has not always been done), we shall be convinced of the
great difficulty of forming any accurate notion of the mosqui-
to-density of any species anywhere. The enquiry would demand
a laborious study of the output, which must vary from week
to week; of the average life, which must also vary; and of the
average numbers found in houses and in mosquito traps
(section 12). It would require the services of a number of
trained "moustiquiers," and the error would amount to say
10%, or more, even with the most careful observations.

(5). Variation of mosquito-density from place to place.—It
would be very interesting to determine the rate at which
the mosquito-density falls at different distances from a
single breeding-place. Stephens and Christophers [3th April
(71 1900) showed that in Freetown, Sierra Leone, the insects
were abundant in houses near certain breeding-waters, but
diminished markedly at greater distances. An exact enquiry
would be very difficult. We could estimate the numbers
caught in houses and traps at various distances from a single
pool in an otherwise sterile area. Here one source of error,
the relative domesticity of the species investigated, would
cause us from the ratios; and again $\pi$ must be the propor-
tions caught should indicate the proportions present. But
other sources of error, facilities for obtaining food and shelter
in different houses, might disturb the results. An empty
farm close to a marsh might, for instance, attract many fewer
insects than a small, crowded village half a mile away. Never-
theless, we know that as a broad general rule, mosquitoes tend
to diminish with distance from their breeding-places; but the
exact curve of diminution has not been ascertained.

(6). Variation of mosquito-density from time to time.—Here,
too, we could count the number of mosquitoes in houses and

¹ See, however, end of (11), Section 66.
traps for a series of days, and the factor of relative domesticity would be eliminated from the ratios. The total variation obviously depends upon two factors, that of output and that of longevity. If both the birth-rate and the death-rate are increased or diminished, the total density might remain the same, a fact which seems sometimes to have been forgotten.

17. Variation of mosquito-density due to food etc.—Abundance of food certainly has a great effect on domestic Culicines, which tend to swarm in crowded and poor habitations. Probably it has a similar effect on sub-domestic Anophelines, though these may not be so much in evidence. I mean that abundance of food probably tends to increase the output, although the total breeding surface remains the same. This would be due to the fact that the females find food more easily and consequently lay more eggs. Thus malaria may perhaps increase in a locality, not because of the increase of breeding-places or rainfall, or because of the introduction of more imported cases, but simply because an increase of the human population has provided more food for the Anophelines (section 30: (9), (12), and (21) ).

(g). Relation of mosquito-output to extent of breeding-surface.

This is a point of great importance as regards prevention. If we reduce the extent of breeding-surface to a given proportion, what will be the exact effect on the number of mosquitoes?

(a) The number of larvae in a collection of water will depend (1) on the number of eggs laid in it, and (2) on the suitability of the water—temperature, shelter, absence of enemies, food.

(b) Probably that number cannot exceed a certain limit; that is to say, there must be a maximum possible output per unit of breeding-surface at any season.

(c) Probably also the actual output is often less than the maximum possible output, the deficiency being due to absence of enough food for the females,
destruction of the adults, inaccessibility of the water, etc.

(d) The maximum possible output per unit of breeding-surface is likely to vary with season, and to be much greater during the warm season when the food of the larvae is probably more abundant, and their development quicker.

From these data we infer as follows:

(e) Suppose that the breeding-surface of a locality is yielding the maximum output, and is then suddenly reduced in extent, say to half or a quarter the previous area. Then a proportional fall must occur in the total output of mosquitoes in the locality.

(f) Next, suppose that the breeding-surface was yielding only a fraction of the maximum possible output when the extent of it was reduced. Then the fall in the total output of mosquitoes may not be so great. The females, which formerly laid their eggs in the part of the area which has been drained, may now resort to the pools which are still allowed to remain, and may increase the output of these by stocking them with an additional number of eggs. Thus, though the total breeding-area is reduced, the part of it which remains may have a larger output; so that the total output in the locality may remain the same as before.

(g) But this compensation has its limits. If the reduction of breeding-area has been great, the pools that remain may often be inaccessible to the females, or may become overstocked with eggs and larvae, for which they cannot provide enough food. At best, the total output cannot exceed the maximum possible output of the waters which remain.

(h) If the drainage operations have been commenced early in the season, before the breeding-season is fully
developed, and if they have not been complete, then, as the breeding-season advances, the waters which remain will still continue to have an increasing output; so that the total output of mosquitoes in the locality may continue to increase in spite of the partial drainage operations. I say that, if any breeding-waters at all are left, the output will increase from month to month as the breeding-season advances to its maximum; but this does not mean that the total output after the drainage operations is not less than the total output in the previous season before the operations. The thoughtless observer, seeing an increase of mosquitoes due to the seasonal increase of output in the waters left undraincd, may jump to the conclusion that the drainage has had no effect. But a comparison of the total output before and after the drainage would probably correct this error. The two figures have frequently been confounded—as, I think, at Milan. Of course, if any breeding-waters at all remain, a certain number of mosquitoes will continue to be poured out, especially at the height of the breeding-season; but it is scarcely likely, Culex pipiens, that a small breeding-surface can have as great a output as a large one, and it certainly cannot have more.

We conclude then as follows:—

(1) That *Culex pipiens* the output must tend to vary with extent of breeding-surface.

(2) But that the two curves will not always exactly coincide. For example, if the breeding-surface is reduced to a half, then the output of mosquitoes will also be probably reduced very considerably; but it may not be reduced exactly in the same proportion. If the breeding-waters are entirely removed, of course, the output in the locality must entirely cease.
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215. Flock-migrations of mosquitoes.—We have hitherto considered the mosquito population of localities as if it consisted solely of insects born in the locality. But, obviously, many of the insects found in any area must have entered from without; and we must now examine the subject of mosquito-migration.

By flock-migration I mean the simultaneous movement of large numbers of animals of the same species in the same direction—such as we are familiar with in the case of wild cattle, swallows, locusts, etc. Does anything of the kind occur with mosquitoes? Howard (1901) quotes a letter in which flock-migrations of immense numbers of mosquitoes are reported to have been twice witnessed by the same observer in America. It was supposed that the insects had originated in a large marsh 35 miles distant; and they were numerous enough to cloud the sky, and bend down the grass with their weight. Nuttall and Shipley conjecture (January 1902) that the phenomenon may be due to "overstocking of a given locality by a species." If it has occurred once, it ought to occur frequently enough to be recorded more often. There is always the danger that a large local hatch-out may be responsible for the occurrence.

216. Visitation of ships.—Mosquitoes frequently visit ships half a mile or more from the shore. We must not infer that they have purposely travelled so far in search of food. Winged animals which have once started on a flight across water seldom have the sense to return. At Highcliffe, England, I once watched numbers of butterflies (P. brassicae) flying out to sea from the shore on a still morning—none were coming back. Birds and insects, lost in this manner and excited with flight, naturally board passing ships for rest. Sometimes, however, a ship anchored close to shore may be attacked by mosquitoes which may perhaps scent their prey from a distance. On the other hand, I have often been on board such ships without noticing many mosquitoes. Once I spent a night in a small open boat, rowed down a river in Burma, but observed at the
time that not a single mosquito attacked us, though the night
was still and warm.

(11) Transportation by ships and vehicle—We have known
*Culex* and *Stegomyia* to breed in water-jugs and flower vases on
board ship, and they frequently bred in bilge-water and wooden
water-barrels. But as soon as the ship starts on her voyage
most of the insects seem to be blown out of the cabins. Nuttall
[1890] says that he once observed dozen foreign species of
mosquitoes on board a ship lying at quarantine in New York.
This was probably a sailing-ship, as the vibration of steamers
seems to prevent the insects from entering. Ballantyne
notices that mosquitoes are brought into Khartum in boats.
Every one who has lived in the tropics has observed that
mosquitoes occur in carriages and railway trains. During the
heat of the day the insects with unwilling to leave the vehicle,
though it is in motion, and may thus be transported consider-
able distances. But vehicles which introduce mosquitoes may
also remove them, and it is absurd to suppose that the small
numbers carried in this way can often influence the malaria rate.

(12) Transportation by rivers and streams—Nuttall, Cobbett
and Nuttall-Shipley [1893] suggested that rivers may trans-
port eggs, larvae and pupae, but I think that most of the
latter would be destroyed before they have travelled very far.

Many people imagine that mosquitoes are carried by winds.
Householders who breed them in their own premises like to
attribute their presence to marshes some miles away. The
authors just quoted state [1901, p. 8] that Fernald described
how mosquitoes at Cold Spring Harbour, Long Island, New
York, were blown there from a distance of 15 miles by the
north wind; but Nuttall and Shipley [1901, p. 8] quote Weeks
as correcting this by showing the existence of many breeding-
place at Cold Spring Harbour itself. When I arrived at
Freetown, Sierra Leone, in 1899, every one thought that the
local mosquitoes came from marshes a mile or more distant:
they were really being bred in every house in the town. I
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could mention many more experiences of the same kind. Statements regarding wind-transportation must be received with great reserve, because here also, a local hatch-out may be responsible for the facts stated.

In Mauritius in 1908 I placed pickets of trained "moustiquiers" at different distances from Clairfont. With instructions to catch all the Anophelines which attacked them. The men sat out late at night and brought us their captures in the morning. Their conclusions were that the insects scarcely move about at all when there is much wind. On still, warm nights, however, especially after rain, the pickets caught both *P. costalis* and *M. mauritiana* half a mile from the marsh. These facts are opposed to those who believe in frequent wind-transportation, but accord with the views of Howard and others, and myself.

Occasionally, of course, a few insects may be swept away by wind, but in most cases wind merely drives them into shelter. In fact, whenever there was any wind our "moustiquiers" caught adults only in sheltered spots behind houses, hedges or woods. I fancy that gnats, like other animals, dislike being swept away from their own haunts into unknown regions.

I have always used the following good argument against the notion that wind transports mosquitoes to any great extent. If this were so, sea-shores constantly swept by sea-breezes ought to be nearly free of them; but I was certainly bare witness to the fact that this was not the case in Madras and Port Said, when I was in those towns in 1871-1874 and 1902. A strong sea-breeze blowing through a house with all the windows and doors open will not, in my experience, drive out the Culicines, nor even reduce their numbers.

(13). Velocity and length of flight. I am not aware of any experiments on these points, but I have frequently observed *Anopheles* flying against breezes which I judged to be blowing at over five miles an hour. They can easily follow a man walking, and perhaps a trotting horse. I suppose that they...
FLIGHT OF MOSQUITOS

fly at the rate of about eight miles an hour, roughly computed.

At this rate an insect might easily cover ten or twenty miles a day, and if it were always to fly in the same direction from its breeding-place, might traverse a hundred miles or more during its life.

Many absurd statements, such that mosquitoes can fly only half a mile or so from their breeding-place, continue to be made. It is not a question of what is their power of flight, or how far they can fly, but of how far they actually do fly on the average.

My proposals to reduce malaria by dealing with the breeding waters were long ridiculed because it was thought that as soon as the local output was checked mosquitoes would rush in from outside to fill up the deficiency. Several eminent biologists held this opinion, and a ridiculous experiment was undertaken apparently in the hope of proving it. In 1903-1904, however, I attempted a carefully reasoned consideration of the whole subject—in that to the interests of malaria prevention; and showed in a lecture [May 1904] that the average wanderings of the insects, and indeed of all animals, must be limited by laws of chance. I will now explain that reasoning as simply as possible.

The random motion of animals from a given point—suppose that some animal is liberated at a given point—for instance, a mosquito from a box—and suppose that it can find its food equally well anywhere in the surrounding country, and is not drawn towards any particular spot, or driven anywhere by wind or other things; what are its movements likely to be? We can imagine that it may possibly continue always to move in the same direction, so that when it dies it will be found at the greatest possible distance from the point where it was liberated. Or it may move for half its life in one direction, and for the other half of its life back again—so that it will die exactly at the point where it started. But both these courses...
will scarcely ever be adopted. In the vast majority of cases, the animal will move for a short distance, first in one direction, then at an angle in another direction, then again at another angle, and so on until it dies. Its movements will resemble those of a grain of dust placed on a level plate in a jolting railway carriage: or the random walk of an intoxicated person in a mist; or that of a cow grazing on a uniformly succulent meadow. What are the chances that when the animal dies or ceases to move it will be found at a given distance from the starting-point?

Obviously, it will most probably be found somewhere near the starting-point. There is no reason why it should move more in one direction than in another. The chances are equal that, at any change which it makes in the direction of movement, it will next move north, south, east or west. Hence its various movements will always tend in the long run to annul each other—so that it will tend to finish near where it began. But there is no certainty that its various movements will annul each other exactly; hence, most probably, it will not be found exactly at the starting-point, but only somewhere near it.

Or we may put the problem thus. Suppose that a million Anophelines are liberated from a single breeding-pool in the midst of a country where they can obtain food equally well at any point, and suppose that we know their average rate of movement and length of life: how many of them will be found at a given moment at a given distance from the pool? Most of them will be found, not exactly at the breeding-pool, but close to it. A few will be found farther away, and a very few at the extreme limit of possible flight.

What precisely will be the ratio of insects at a given distance from the pool? In my lecture just mentioned I attempted a partial mathematical treatment of the problem, but the matter was beyond my mathematical powers, and I therefore referred it to Professor Karl Pearson, who, with J. Blakemore, obtained
a correct and complete solution, based on the laws of chance [1926].

It is not possible to give their complicated mathematical analysis here, but it will presently mention some of their results. Besides its application to the prevention of mosquito-borne diseases, the mathematical theory of migration has manifest and important applications in general biology, as, for instance, to the theory of evolution and the study of local variation of races.

The general results obtained from the calculations may be put as follows:

1. Unless mosquitoes are driven or driven in any particular direction or directions, their number will tend to be greatest somewhere near the breeding-pool, and to diminish progressively at greater distances from it.

2. For example, if the mosquitoes are very numerous, then *culex palaearcticus*, the breeding-pool is likely to be near at hand.

These laws are confirmed by the general observation of many workers and of the public. For example, Stephens and Christeners [July 1902] conclude that the "flight" of *M. culicifacies*, *X. fuscipes*, and *X. steppheni* in Nagpur, India, is "frequently a quarter of a mile, but does not extend to half a mile."

3. Exceptions—These will be due to (a) mass-migration, if it occurs; (b) carriage by vehicles, boats and wind; and (c) more generally, to food-pursuit.

The law of random scatter applies only if the country affords equal facilities for feeding in all directions, but if this is not the case, the insects must, of course, go where they can find their food. Thus if there is only one breeding-place and one feeding-place somewhat far apart, the females must always reverse that distance between feeding and laying their eggs; and if the distance is great, probably few of the females will succeed. If there is only one feeding-place in the midst of many breeding-places, such as a village surrounded by marshes,

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1 This paper is not mentioned in the medical text-books.
To understand this, we suppose that the mosquitoes (or other animals) are breeding as usual on the left—that is, in the Area of Emigration, and that many of them are wandering across the boundary into the sterile area (Area of Immigration). The curve beginning on the left shows the fall of the mosquito-density. Slow at first, it increases rapidly as we approach the boundary from outside. Exactly at the boundary it is exactly one-half. Inside the boundary it continues to fall, rapidly at first, and then more slowly as we approach the centre of the sterile area. At the centre, if the patch is sufficiently large, it should be nearly or practically zero.

The following diagram from my paper shows the same thing in plan.
We should also understand the following simple propositions. If a straight line is drawn across a country in which mosquitoes (or other animals) are wandering equally and at random, then as many will wander from left to right of the line as from right to left. Moreover, the longer the line the more animals will wander across it, *Culex pipiens*, in unit of time. This should hold also for circles. Thus, if we draw two circles, one 100 metres in radius and the other of 1000 metres, ten times more animals should wander across the circumference of the latter than across that of the former. Thus the number of immigrants into the large circle should be ten times the number into the small one. But the mosquito or animal density is obtained by dividing the total number of animals by the size of the area, and the area of the large circle is $100 \times 100 = 10000$ times that of the small one. Thus, though ten times more mosquitoes actually wander into the large circle, yet the average mosquito density due to immigration alone in the large circle will be only one-tenth that in the small circle. Now if both these circles contain sterile areas, the mosquitoes within them can consist only of immigrants. Hence the total mosquito density in the large sterile patch will be only one-tenth that in the small one. In other words, the larger the sterile patch the smaller will be the mosquito density due to immigration into it from outside. That is, the larger the area of drainage the more effective it will be.

It has often been thought, absurdly enough, that the mosquitoes in an area may not always be reduced by rendering it sterile. This can never happen *Culex pipiens*, because the number of immigrants can never equal the number of immigrants plus the number of natives. But if the area is very small it may be so few natives that the reduction after it is sterilised will not be noticeable. But by suitably increasing the radius of the sterile patch we can reduce its average immigration density to any small figure we please.

Of course, the immigration density is not uniform, but,
as already stated, begins at the boundary, at a fraction of
the normal density, and from that fraction diminishes rapidly
towards the centre, where, if the sterile patch is large enough,
it may become practically zero.

Frosen and Blackburn have made some exact estimates
based on rough estimates supplied by me. For example, in
a circular sterile patch one mile (1.6 kilometres) in diameter
the mosquito density should be reduced at the boundary to
about 25% of the normal density; to 18% a quarter of a mile
from the boundary; and to 9% at the centre. If the sterile
patch is two miles long and one mile broad, the central
density should be 5% at the boundary, 11% halfway to the centre,
and 2% at the centre. In section 30 I attempted to calculate
the probable fall in the malaria rate which may result from
a decrease in the number of mosquitoes.

30. Explanation of Various Phenomena.—In the previous
sections I have endeavoured to give the general theorem of the
spread and prevalence of malaria. We have now to apply
this theorem to the explanation of certain phenomena which
have been observed in connection with the epidemiology of
the disease.

From section 28 (equations 4 and 7) we have the two
following formulae:

Variation Formula, \( m = m_0 + \text{Proc.} \times (1 - m_0) \times m_1 - \text{Proc.} \times m_0 \)

Static Formula, \( m = 1 - r \text{Proc.} \times (1 - m_0) \times w_1 - 0.02 \times m_0 \) (say)

The first formula suggests the manner in which malaria
varies in a locality. Here \( m \) is the proportion of infected
persons at the beginning of the enquiry; \( m_0 \) the proportion
of different carrying Anophelines to each person (healthy or
infected) during the enquiry; \( r \) the rate of recovery; and the
proportion of Anopheles which succeed in biting men; \( r \) the proportion of Anopheles which succeed in maturing the parasitae; \( s \) the proportion of patients with gametocytes in their blood; and finally, \( a \), the proportion of infected persons at the end of the period of enquiry. Here \( a, r, s, t, \alpha \) are all fractions. I suppose conjecturally that if the enquiry lasts one month \( d = r = a = t = \alpha = 0.2 \).

The second formula suggests the final or static level \( s \), to which the proportion of infected persons falls so long as the proportion of Anopheles \( a \), and the other factors remain about constant.

The exact numerical values of \( a, s, t, \alpha \) do not materially affect the general argument. The equations omit several minor factors, but are still useful for giving precision to our ideas.

113. Connection with marshes.—The fact that malaria tends to be very prevalent near marshes was observed by the ancients, has given the name paludism to the disease, and is perhaps the most fundamentally important fact of our subject. It is easily explained because most Anopheles breed principally in marshy waters, and because, by the law of random scatter in (14) of last section, they will generally tend to be most numerous near their breeding-pools. By the static formula, the larger \( a \) becomes, the nearer \( s \) approaches to unity—that is, almost the whole population becomes infected. For example, if we recede from an isolated marsh or other isolated breeding area, the smaller the mosquito density becomes, and so falls in value. When we reach such a distance from the marsh that \( a \) becomes 0.4 (conjecturally) or less, the static malaria tends to disappear altogether.

Of course there are many factors which may possibly modify the exact paludal-peripheral distribution of malaria; such as the existence of abruptly-rising ground, or of open water, or of thick forest close to the marsh. But (1) a strong wind continuously prevalent in one direction. Species of Anopheles may affect the radius of distribution. When there are many
scattered breeding-places within range of influence of each other, the malaria will tend to be more equally distributed.

The fundamental fact has been noticed, if not studied, everywhere, especially in Italy. Stephens and Christophers [April 1902], in a paper on the factors which determine endemicity, conclude from a number of scattered observations in India that "other things being equal, there is a direct relation between the extent and proximity of breeding-grounds, the number of Anophelles in the houses, and the endemic index." Unfortunately they give only ratios, and these only for entire villages at various distances from the breeding-grounds. In 1908, C. E. P. Fowler and I made an exhaustive study of spleen rates of children in houses scattered close round the Claitfond Marsh in Mauritius (section 31 [ix] and map opposite). We found an extremely rapid fall in the spleen rates even at a distance of 200-300 metres from the principal pools of the marsh. In the three rows of barracks of the British soldiers, the nearest of which was 820 yards (777 meters) from the nearest pool of the marsh and the furthest about 200 metres further, Colonel Peterkin, the Principal Medical Officer, found that the ratios of malaria cases to men were 31/206 = 150/1000, 22/20 = 88/1000, and 2/62 = 32/1000, in the successive rows. Many other instances might be cited from the literature.

The definition of the word "marsh" as here employed is a very important point. Webster, for instance, defines a marsh as "a tract of soft wet land commonly covered partially or wholly with water." This definition includes the marshy borders of rivers and lakes, etc., but we must extend it, for the purpose of our present technical meaning, to exclude the idea of permanence. In our sense, marshes may be quite temporary—may exist only for a few weeks during the rainy season, or season of floods, or wet cultivation. The reader must not imagine that Anophelines breed only in permanent marshes. I have often thought that water-logged country...
may often be really less favourable to them than a usually dry country which may be covered during the rainy season by extensive temporary marshes. In permanent pools, the larvae probably have many enemies—fish, beetles, tadpoles, other larvae—which cannot live so easily in the shallow, evanescent pools formed by rain at certain seasons. It is quite possible that for this reason a unit of temporary marsh has an actually larger annual Anopheles output than a unit of permanent marsh; and this consideration may help to explain the great prevalence of malaria in certain dry countries, as in the north of India.

(2). Connection with soil.—Obviously, an impermeable soil is likely to possess more collections of surface water than a loose, porous one, and thus to increase the number of Anophelines. A sub-soil stratum of rock or clay has often been mentioned as increasing malaria.

It is possible, also, that certain soils are favourable to the breeding of the local malaria-bearing mosquitoes, while others have the opposite tendency.

There is much old literature on this point—written when malaria was attributed to the soil. After considering it, I think it is scarcely worth reference, although much of the work was carefully done. There is never any proof that the variations of malaria attributed to differences of soil were not really due to other causes. I am far from saying that soil exerts no influence on the endemicity; but I can find no decisive evidence that it does so, apart from the merely mechanical effect of permeability. The matter deserves more exact study by modern methods.

(3). Connection with slope.—Abrupt hillsides have little malaria as a rule, but Anophelines often breed in dry beds of torrents, as (for instance) described by F. Smith and A. Pearse in Sierra Leone (1904). I was infected in 1897 in such a place, Kalbitti, near Ootacamund, India (February 1898), and the native servants of the house were attacked there also. Small flat valleys among
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Mountains are apt to be very malarious. Slope acts mechanically on the drainage, but the labour and heat of climbing predispose to chills and relapses.

Flat plains at the foot of mountains—called zirias in India—are notoriously unhealthy. This is due to the fact that they receive all the surface-drainage of the rain on the mountains, the same flooding from which immediately stagnates on the flat levels. After heavy rain a whole mountain seems to weep with moisture at its base, springs often appearing considerable distances away on the plain.

Whether mosquitoes often find their way far up slopes is doubtful. In 1892 we observed scarcely a single Anopheles in the barracks at Tamer Hill, a small open hill in the centre of Freestone, Santa Fe, with numerous breeding pools only about 500 metres distant. Infections among people living at a small height on slopes is probably more often due to the visits they pay to the plain, rather than the visits paid by the Anopheles of the plain to them.

4. Correction with vegetation—Several Anopheles are known to breed in plants and trees. Certainly, many Culicines do so, and also seem to like the shelter from sun and wind given by dense vegetation. Our "moustiquaires" in Mauritius had no difficulty in securing Anophelines in the densely wooded "river reserves." But I do not know any numerical researches which have been made to prove that any malaria-bearing species abounds more in woods than on open ground (see, however, sections 37 and 63).

It has been proved statistically by Mr Walter of the Mauritius Observatory that the damp exhaled by trees increases the number of rainy days, and especially the afternoon rainfall so frequently seen in the tropics. For this reason alone, therefore, trees should favour the breeding of mosquitoes.

It is generally held that a screen of trees shuts out malaria and mosquitoes—this being one of King's original arguments in favour of the mosquito theory. Stephens and Christophers
also accept the hypothesis. It is a likely one, but better proof is required.

The fact that the true *Plasmodidae* have hitherto been found only in men, monkeys, bats, squirrels and perching birds is a curious one, which suggests an arboreal connection.

(3) *Koedoe* with rainfall is manifestly due, in the case of summer rain, to the increased mosquito output. Rain also tends to bring on relapses, and therefore to increase the factor—since patients with frequent relapses tend to show more gametids than those without them (section 20 (b)). Thirdly, I think that it increases the biting factor, A, and quite possibly reduces the recovery factor, F. Hence, in all counts it must tend to increase the malaria.

*Winter* rain may possibly reduce A, but, if the winter is cold enough, can have little other effect. This in Greece most of the rain falls in the winter, when there is little new infection.

Much *giving* rain, however, has a very disastrous and well-known effect, as it fills the pools just when the weather is becoming warm enough for breeding. This has been especially noted in Greece.

Statistics support the common statement that malaria inoculation occurs most frequently at the beginning and the end of great summer rains. At the height of these rains, when they are copious, the ground is often covered with more or less running water, frequently containing myriads of small fish, and too disturbed for much breeding.

On the other hand, in countries with small total summer rainfall, the maximum breeding is more likely to occur at the height of it. There was a bad outbreak in the north of India in 1908, when most of the rainfall was concentrated in the month of August.

Innumerable statistics showing the connection between rainfall and malaria might be reproduced here. Unfortunately, while they prove the existence of the connection, they do not enable us to discriminate between inoculations and relapses.
Most probably the variation formula is affected by change in all the factors mentioned above.

6. **Connection with temperature.** Like that with rainfall, it is probably due to increase of all the factors and decrease of the recovery factor consequent on exposure to heat or sun. Warmth is, of course, an essential to typical breeding, but great dry heat must tend to desiccate the pools.

An important question remains to be considered. In low latitudes the temperature is generally uniformly hot all the year round, so that the Anophelines should be able to breed at all seasons, especially where the rainfall is also fairly evenly distributed. But in higher latitudes, the breeding can occur only during the short hot weather. Hence we should infer that the Anopheline factor must always be higher in the former, and the malaria more abundant. But statistics often show that just the opposite happens. For example, in the north of India, where the winters are sharp, the total fever rate is generally considerably higher than in the south, where there is no winter. Malaria is, or was, intense at Peshawar in the extreme north, and scarce in Calcutta, Madras, Rangoon and Colombo. But this law does not always hold, for malaria is common in Panama, Colom, Lagos, Fernando Po and Port Louis on Mauritius, all of which have a climate very similar to that of the four Indian coast towns (I write from personal acquaintance).

The probable explanation is as follows. So far as we can judge, not all the Anophelines can carry malaria, and various carrying species differ in carrying power, thus modifying the carrying factor, etc. It does not follow that all the Anophelines of a country those with high carrying power breed best in a uniformly warm climate. Stephens and Christophers showed this well in their paper just referred to. Thus, *M. roseni* with a low carrying power, prevails most in Calcutta and Madras, but in Colombo, just below.

7. **Connection with altitude.** It is well known that malaria
tends to diminish and cease at an altitude of about 500-1,500 metres above sea-level. The exact limit probably depends upon the latitude. I was infected in 1897 at 1,800 metres in the Nilgiri mountains in India. The disease abounds at Cilaos, Réunion, at 1,214 metres. The text-books quote many similar cases, but these often require verification. It is more interesting to ascertain the gradual fall in the malaria curve with altitude. Stephens and Christophers, misled, I think, by insufficient random sampling, thought that altitude under 4,000 feet (1,219 metres) "does not seem to play an important part," but our copious figures of spleen rates in Mauritius (section 22) prove that it does. That island, consisting almost everywhere of plateaux sloping gradually downward and therefore being capable of breeding at all the altitudes (from 0 to 549 metres), gives an excellent opportunity for the enquiry, as will be seen by study of the table referred to. The carrying Anopheline was probably entirely M. annulatus.

As is well known, the temperature of the air tends to fall about 1° F. for every 300 feet of altitude (about 0.56 C. for 100 metres). The general decrease of malaria with altitude is probably due mostly to this fall in temperature, but in Mauritius, and perhaps in many other places, other factors besides temperature may retard the breeding of the local carriers at the higher levels. The following table, calculated from that in section 22, gives the spleen rates and average spleen for groups of altitudes:

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>0-300</th>
<th>300-600</th>
<th>600-900</th>
<th>900-1200</th>
<th>1200-1500</th>
<th>1500-1800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall of Temperature (°F)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Spleen Rate</td>
<td>44</td>
<td>47</td>
<td>57</td>
<td>83</td>
<td>109</td>
<td>147</td>
</tr>
<tr>
<td>Average Spleen</td>
<td>295</td>
<td>308</td>
<td>309</td>
<td>317</td>
<td>319</td>
<td>312</td>
</tr>
</tbody>
</table>

The exceptional figures at 1,200-1,500 feet were due to the epidemic round Clairfond Marsh. Apart from these, the fall, both in spleen rates and average spleens, is not noticeable under 600 feet, and then becomes very rapid up to 1,200 feet—after which, under normal circumstances in Mauritius, the malaria
is slight, or possibly only important. Other facts will be elicited
when governments get into the way of collecting spleen rates
annually, as they should do.
194. Comparative freedom of centre of towns.—It is generally
stated as a commonplace that malaria abounds less in the
centre of towns and more in the suburbs; and, from my own
general observation, this appears to be the case in all the larger
towns known to me. But the matter requires strict enquiry by
measurements of malaria made on proper principles from the
centre outward.

The probable explanation is that the Anophelines, though
they may breed in small numbers in wells, cisterns, gutters,
water tanks, etc., in towns, yet cannot generally
propagate so copiously and freely there as in the more open
regions in the outskirts. Probably, also, as the wealthier people
generally live in the better built and paved centre of a city, the
recovery factor is increased and the gametoid factor decreased
there by the good medical treatment usually accessible to these
classes. But there is also the following factor.

195. Effect of density of human population.—Suppose that in
a locality the mosquito population remains the same, but
that the human population varies; what will be the effect of
this variation on the malaria ratio? By the static formula
\[ \text{ratio} = \frac{1}{1 + 40a} \]
but \( a \) is the number of Anophelines, not in unit
of space, but per unit of human population. If therefore, the
latter is doubled while the total mosquito population remains
constant, \( a \) will be halved; and so on. Thus the static malaria
ratio tends to decrease with increase of the density of the
human population. That is, other things being equal and the
Anophelines being supposed to breed equally everywhere, the
malaria ratio should be higher amongst a scattered rural
population than in a dense urban one, because, evidently, the
number of Anophelines per person will be less in the latter.

But I am not sure that if the human population varies, the
mosquito population will generally remain the same. Unless
the latter find abundance of food independently of the former, their numbers are likely to diminish if the former diminishes (section 29 (7)). This will depend largely upon whether the local carrier is a domestic, sub-domestic or wild species, and on other circumstances.

If the total mosquito population varies directly with the human population, the factor $a$, and therefore the static malaria, should remain constant—that is change of density of the human population will not affect the result.

If the mosquito population diminishes as the human population increases, the malaria ratio should fall greatly—as in well-drained towns. If the former increases with the latter but more rapidly, the malaria should increase.

It may happen that when the human population begins to increase the local breeding surface is already yielding its maximum output of mosquitoes. In this case the increase of the human population should cause a decrease in the static malaria ratio (section 29 (8)).

In all these cases the malaria ratio is not, of course, the same thing as the total number of patients.

If the local carrier belongs to a species or variety which feeds almost entirely upon man, and if the human population is greatly reduced, it may perhaps follow that this species can no longer continue to thrive in the locality—so that the malaria should die out. d'Herel showed me a large marshy area in Mauritius which he said was formerly thickly inhabited; but the disease became so prevalent there that the people deserted it in large numbers. Now it contains only a few scattered huts, the occupants of which show a low spleen rate (with P. vivax).

(10) The "regional factor."—It often happens that two neighbouring tracts of country, apparently similar in all respects such as climate, breeding surface, habits of people, differ largely in the malaria ratio. Stephens and Christophers [25th April 1902] attributed such variation to "undefined causes which we have termed the regional factor. The regional factor
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may be largely due to species, but more accurate and detailed observations on the distribution of Anopheles and malaria are necessary before this can be decided. It may be due to many small things which though not very apparent to the observer, may largely affect the mosquito factor. Thus the local carrier in the larval stage may require a certain kind of food which abounds in water lying in certain soils present in one locality and not in others. Again, certain soils may favour special enemies of the larvae of the carrier—small fish, beetles, certain mosquito larvae, parasites; while certain classes of vegetation may favour enemies of the adults. All these are likely to be very potent causes of variation in the mosquito factor, though they may not be easy to detect without long enquiry. If we attribute the regional factor merely to "species" of carriers, we have still to "explain our explanation" since we must then why a given species abounds more in one area than in another.

Hence I define as follows: By regional factors I mean all those local conditions, apart from mere extent of breeding surface, which influence any of the mosquito factors, that is, local conditions which influence the output per unit of surface, the biting power, and the maturing power of the local Anophelines.

111. The species factor. This influences and the biting and maturing powers of the carriers, which probably differ largely with the species or even variety of the carrier. Where these factors are high, a lower number of Anophelines will produce a given amount of malaria.

Thus tropical Africa appears on the whole to be more malarious than India—that is, the chances of becoming infected in unit of time and space in Africa are said to be greater in Africa than in India. This may be because good carriers such as P. costalis and M. fuscus abound more in the former. In India the bad carriers, M. naini, seem often to crowd out the more pathogenic species.
The local prevalence of good carriers or bad ones must depend not only on regional factors but on the general zoological laws which determine diffusion of species.  

12. The social factor. — The factor depends not only on the appetite, energy and enterprise of the mosquito, but also on the intelligence, social status and habits of their victims. Stupid, poor, lazy people, living in badly-made huts, without much clothing and without mosquito-nets, are sure to be bitten much more easily than more civilized races. People who burn wood or cow-dung in their houses in the evening, or who rub their skins with oil, earth or sandal-wood, or who close their rooms at night, may perhaps be bitten less than others. The subject is too complex for detailed examination here. The habits of man and mosquito are probably often correlated. Thus where the principal carrier is an out-door biter, people who sleep or work at night in the open are likely to suffer. Alcoholism, opium, etc., lead to neglect of precautions. Children are sure to be easy victims. Farm work and dogs may satisfy many insects, and fans and initState away others.

Neglect of precautions against being bitten is likely not only to increase the biting factor, but also, by section 29 (7), the total number of mosquitoes.

Famine, poverty and other diseases will reduce the recovery factor.

13. Possible effect of malaria on the Anophelines. — As early as 1868 I thought it possible that the parasites might injure their insect hosts, as well as their human ones. If this happens we can readily understand that an epidemic of malaria might tend to limit itself by killing large numbers of the carriers as well as men. Thus, during an epidemic year, so many of the insects might die that the breeding might subsequently be reduced for some time. But there are reasons against this view. I could never satisfy myself that C. fatigans, even when
extremely heavily infected with *Plasmodium*, died sooner than when not infected at all. Probably they did so, but only to a slight extent. Then again, only a small percentage of infected mosquitoes are heavily infected, so that the malaria infection is not likely to make a material difference in their death-rate. Lastly, even a severe epidemic among them will quickly be compensated for by their rapid proliferation.

(4. Seasonal variation. — This is a matter of universal observation. In a general rule in the southern hemisphere the disease reaches its maximum prevalence in the autumn, say October or November. At that point, a rapid decline, the *winter fall* generally begins, and this continues for several months until early spring, say February or March, when the winter minimum occurs. The *spring rise* now takes place, and the disease tends to increase with more or less regularity until the next autumn maximum. Of course, the seasons are reversed in the northern hemisphere. Numerous illustrative statistics might be given, but every one is acquainted with the phenomenon, and the examples in section 20 will suffice for our present purpose (note that in the Italian figures the minimum is reached in June).

The causes of seasonal variation will be apparent from a study of the variation formula given at the beginning of this section. Thus the *winter fall* is probably due to diminution of the factors *k* or *l* in consequence of the cooler temperature or drying up of the rains, or of both; and also possibly to increase of the recovery factor owing to the more bracing climate. On the other hand, the *spring rise* is probably due to just the opposite changes in these factors, and possibly also to the emergence of *Anopheles* which have been hibernating through the winter.

In the tables in section 20 I have given the ratios between the average admissions for successive months. These can be compared with the variation formula by supposing that $m_k$ is the malaria ratio for any given month, and $m_0$ the malaria ratio
for the next month. Then, dividing the variation formula throughout by \( m_0 \), we have:

\[
\frac{m_0}{m_0} \approx 1 + \frac{\partial}{\partial t} \left( 1 - m_0 \right) - r.
\]

Thus, take the monthly averages and ratios of the native troops, and suppose that only the number of men actually infected were admitted (section 31 (5)) into hospital every month. Then, out of 43,330 men there were on the average 922 infected men in February and 1,030 in March. Thus:

\[
\begin{align*}
\text{February:} & \quad m_0 = 922, \quad m_1 = 1,030, \quad m_0/m_1 = 0.90, \\
\text{March:} & \quad m_0 = 922, \quad m_1 = 1,030, \quad 1 - m_0 = 0.09.
\end{align*}
\]

and therefore,

\[
\begin{align*}
\frac{m_2}{m_1} = 1 + 0.90 \text{ Rate} - r.
\end{align*}
\]

Supposing that \( b, \gamma, \delta, \epsilon \) have the values assigned at the beginning of this section, we calculate from this that \( s = 0.12 + 0.2 \times 0.049 = 0.65 \). That is, as a rough estimate, there may have been about 65 carrying Anophelines per person during the month February to March in order to increase the infected persons from 922 to 1,030, and the admissions from 461 to 525.

Similarly, in order to cause the great rise in admissions among the native troops from averages of 1,859 in September to 2,955 in October, we may estimate roughly that 175 Anophelines may have been present. In order to cause the commencement of the winter fall from 2,955 admissions in October to 1,932 in November, we shall have from the formula a negative number for \( s \)—that is, according to our data, there should be no Anophelines biting at the time. But of course our data are only speculative ones, and, as already stated, the factors \( b \) and \( s \), as well as the Anopheline factor, are likely to vary with seasons. Moreover, my estimate that the recovery factor \( r \) equals about 0.2 is probably too high for the earlier months of infection.

133. Annual variation.—This also is a matter of general observation. In every country there are “good years,” “bad years,” and “years of epidemic.” This variation, when it occurs over large areas, is probably due principally to the influence of
climate, i.e. rainfall, number of rainy days and temperature, on
the Anopheline factor.

In the statistics of section 30, the numbers of admissions
differ not only for the whole years, but also for the same month
in different years, and for the European troops, native troops
and prisoners, respectively, during the same year.

It is interesting to note that a considerable rise in the total
annual admissions may, by our formulae, be produced by a
comparatively small rise in the Anopheline factor. Thus
among the native troops there were 11,293 admissions in 1903
against 19,507 in 1904. But by the static formulae the former
number would be given by 80.55 and the latter by 80.70. It
would be almost impossible, for the reasons given in section 29,
4, to detect this increase in the number of Anophelines (28)
by ordinary observation. Hence the unwary observer might
assume that the rise in the number of cases was independent
of the rise in the number of Anophelines. In fact this is one
of the principal stumbling-blocks of students. They observe
a considerable annual variation in the number of cases with­
out, apparently, any great Anopheline variation. But I doubt
whether an Anopheline variation of as much as 50%, or even 100%
would be easily detectable by the very unsatisfactory methods
of counting mosquitoes at present known to us. If there are
over 40 different Anophelines to each person per month, we
should probably be able to find only two or three daily in his
house—and possibly less if the insects are "wild" ones. This
number might be doubled or trebled without producing a
change which would be readily noticed even after careful
observation, and long-continued random sampling would be
required to establish the variation over a tract of country. Yet,
as we have just calculated, a 28% increase in the Anophelines
might cause a 42% increase in static malaria—that is, an increase
of admissions from 11,293 to 19,507.

While, I think, the annual variation is generally due to
climatic causes, it is very possible that other factors often
EFFECT OF IMPORTED CASES

Influence it—such as poverty caused by increase in the cost of food (which would diminish the recovery factor) or movements of the population which might act in various ways.

(16) Effect of imported cases.—In section 28 I argued that, whatever the original number of cases may be, the malaria in a locality tends finally to settle down to a fixed static ratio determined by the various constants. Thus if we take the case of a village of 1,000 people, half of whom are infected to begin with, with 60 Anophelines per person, the rate would fall until, finally, about 333 persons are always infected. If we had started in the same village with the same number of Anophelines but only one infected person, then the rate would rise until the same number of infected persons are found. But the reader must not infer that the original malaria ratio is of no consequence—that it does not matter whether many cases are imported or not. True, the ultimate static ratio should be the same, but many months may elapse before this limit is reached. If there have been about 333 cases in the village for months or years past, and we now add 167 imported cases, then (neglecting the small change in the total population) we should have 500, 475, 455, 435 and 414 cases in the four following months, that is, 33, 61, 122, 185 and 240 more cases than there would have been in the village if no imported cases had been introduced. This would probably be looked upon by the villagers as a serious epidemic due to some climatic cause.

On the other hand, suppose that there have been 40 Anophelines per person in the village. Then the static malaria there would be zero. But if 500 of the villagers are now replaced by 500 infected persons, the 40 Anophelines, though insufficient to maintain static malaria, would be sufficient to spread the disease to some extent among the villagers; as will be seen by comparing examples 3 and 6 of section 28—that is, the examples with 40 and with 0 Anophelines. In four months the former will have 500, 450, 400, 350, 300
cases, some of them among the healthy villagers; and the latter will have only 500, 400, 300, 256, 205 cases, all among the imported persons. Thus in the former there will be 50, 89, 120, 143 cases among the villagers, who will, of course, suffer from an epidemic. But in the end the epidemic will die out.

In this village then, 40 Anophelines per person will suffice to spread the disease to some extent from the imported cases to the healthy villagers, though the various small epidemics which may be caused in this way will tend ultimately to die out. But suppose that owing to the blocking of some stream the Anopheline factor is increased to 60. The imported cases will now not only spread the disease to the healthy villagers, but the epidemic, instead of dying out, will continue to increase until the static limit of one-third of the population is reached. The village, which previously suffered only from sporadic out-breaks due to imported cases, will now become permanently infected. Yet this great change will be due merely to the small increase of Anophelines from 40 to 60 per person—an increase which few observers would be able to detect.

It is unnecessary to labour this matter further— I have already laboured it perhaps too much. The point to be understood is that a small Anopheline variation—too small to be easily observed—may yet make a great difference in the local endemicity. Below a certain figure the Anophelines will be, according to the laws of chance, too few to produce enough new infections to keep pace with the natural recoveries. Above that figure they will be sufficient for the purpose, and the malaria ratio will rise to a definite static limit.

So far, this theorem has been already given in section 28; but we now perceive another point of importance. Though the Anophelines are too few to maintain a static endemicity, yet if any at all are present they may suffice (provided that the other factors, i.e., do not possess prohibitive values) to cause small temporary spreadings of the disease from imported
isolated abnormal areas cases among the local population. Only in the case where there are practically no Anophelines will the imported cases have no effect at all. The reader will easily grasp this law by comparing the examples in section 28.

The reader should also remember another point. Our formulae are based upon the calculation of average chances. Thus, if the average Anopheline factor is over forty, and a single case of malaria is imported, we argue that the chances are that the disease will spread in the locality. We do not say that the disease must or will spread to a certainty. The laws of luck come in here. The distribution of Anophelines cannot be absolutely uniform in any locality. The imported case may come to reside at a spot where there are few Anophelines, so that the chances are that the disease will not spread at all. Or he may reside where the Anophelines are a little more numerous so that only a small temporary epidemic may be caused. Or, if he happens to live where there are many Anophelines, a permanent rise in the malaria rate may be produced. Yet in all these cases the average Anopheline factor for the whole area under consideration may be anything. Thus, again, the imported case may have no gametids in his blood, or he may arrive in winter and recover before the mosquito season; or he may use mosquito-nets. This will be a case of good luck, but by bad luck none of these events may occur, and an epidemic may be started or increased.

We must now consider some special cases of importation.

17. Isolated supermalarious or infraanemicous areas—Suppose the case of a country in which the static malaria is generally low, but in which an isolated area becomes, from any cause, more highly malarious: what will be the effect of that patch of high endemicity upon the health of the surrounding country of low endemicity? Evidently, unless the inhabitants of the supermalarious patch are strictly confined to it, some of them will tend to wander away from it, especially if, as often happens, they are actually driven out of it by its
unhealthiness. If there are any Anophelines at all in the
surrounding country, these emigrants, when infected, may cause
local spreading, slight, severe, transient or permanent, according
to the local factor. In any case they will tend to increase the
surrounding endemicity. To calculate the increase from the
variation formula, we must add month by month, the reported
cases to the number of cases remaining over from the previous
month. Thus, though the static malaria ratio of the surrounding
country might be naturally low, the continued importation of cases
from the focus of high endemicity might raise it very considerably.

It may be said that this process cannot continue for ever,
because the focus would soon become depopulated. This
certainly happens in some unhealthy spots; but in others
the population of the focus is maintained by constant immigration,
so that it continues to be a permanent source of danger
to the neighbours. And its influence may be felt for consider-
able distances.

Now, consider the concrete case—that in which an isolated
patch of low endemicity exists in the midst of a larger area
of high endemicity. The effect should be just the opposite.
There should be obviously less malaria in the whole country
than if the inframalarious patch had not existed at all; and
the larger the healthy patch, the larger its influence will be.

In other words, we assume that inequalities of malaria
distribution have results similar to those of inequalities of heat
distribution or mosquito distribution. The superheated objects
or supermalarious ones tend to add heat or malaria to the
surrounding objects or areas. But I am not clear that this
resemblance always holds. Thus the people, and perhaps the
Anophelines, in the supermalarious patch may, after a time,
become so immune that they will no longer add very much
to the surrounding ratios. Conversely, the non-immunes in
an inframalarious patch may raise the ratio there owing to
"extraneous infection" (15).

(18). Effect of mass -migrations.— Suppose that a large
number of persons, with a given malaria ratio, are suddenly and simultaneously moved into a country possessing a different malaria ratio; what will be the effect? Such events frequently happen, as when a regiment of soldiers coming from England or from a very malaria country is moved into a moderately malaria-country, or when numbers of convicts are collected in a locality which has a different malaria ratio from that in which they were collected.

The effect will probably be that there will be an epidemic in both cases. An introduction of non-immunes from England is sure to suffer to a degree determined by the local factors. Its own men will be the principal ones to suffer, but the numerous fresh cases among them will tend to react on the local population. In the case of the introduction of a supermalarious regiment, the surrounding local population will suffer more and will in turn react on the men of the regiment. In both cases the malaria ratio will ultimately tend to settle down to the static ratio of the locality. Examples of both of these cases are of frequent occurrences. Large bodies of labourers collected for various kinds of engineering works are liable to cause outbreaks, either among themselves or among the surrounding population, according to the respective endemic ratios and the local factors. This will be especially the case if the aggregation of human beings causes an actual increase in the local anthropoline factor $\gamma$. In such a case the aggregation may have all the bad effects of a patch of high endemicity described in the last subsection.

(125) Extraneous infection—By this I mean the infection of people during occasional visits outside their usual habitations—a very important case. There are many villages the malaria ratio of which under natural conditions would be low, but in which it is maintained at an unnaturally high level by the fact that the inhabitants work in more malarious areas at certain times of the year. Thus in the village of Mali ($373$ inhabitants), situated several hundred feet above the Plain of
Kopais in Greece, I found malaria infection in twenty out of forty children examined [1926]; but there were scarcely any possible breeding-pools among the broken hills round the village. The apparent anomaly was easily explained by the fact that every year nearly the whole population descends to the plain for the harvesting (in August the most malarious month) and camps there for days or weeks at a time. As the most malarious months are also generally those of the greatest agricultural activity, extraneous infection is probably one of the principal equalisers of malarial distribution. In fact, the result is the same if the factors of endemicity are temporarily raised in a given locality, or if the people temporarily migrate to another locality where the factors of endemicity are higher. The local endemicity depends upon the local factors, only if the local population remains stationary. Of course, if there are any local Anophelines at all, persons infected extraneously will tend to spread the disease to some extent among those who do not have the locality. Thus adults infected while harvesting at a distance may infect their children when they return home.

(30) Slow changes in endemicity—Seasonal, annual and other variations such as we have considered are constantly occurring in every malarious country; but, besides these, certain slow but persistent changes, sometimes affecting very large areas, are often observed, or at least reported. It is stated that a whole country is gradually becoming more and more, or less and less, malarious. As undeniable examples I may quote the entry and increase of malaria in Mauritius, and its disappearance from Britain. How explain the phenomena? They may be due, not to one, but possibly to any or all the factors concerned in the malaria equation. Let us first consider each of the possible factors in turn.

(a) The Anopheline factor, that is, the number of carrying insects per person, may slowly and persistently vary. As shown in (15), a scarcely-appreciable variation in this factor...
may produce a striking change in the endemicity. Thus with 60 Anophelines per person the static malaria ratio should stand at about one-third, but it should stand at double that with the Anophelines at 120. Yet few persons would be able to observe this difference in the number of the insects; and as no census has been taken in the past, the scientific student would possess no standard for comparing the present with it. Yet many things may occur or concur to influence this factor to a considerable degree.

Thus it is well known that long but inexplicable undulations occur in the weather-curves. These often affect only certain tracts of country, and have marked results upon the local crops and prosperity. They may thus quite possibly make a considerable percentage of difference in the Anopheline output, besides tending to influence the recovery factor. It would be difficult to state precisely what the exact effect of the weather might be. Excessive rainfall might either increase or decrease the Anopheline output, especially of certain species, according to local breeding conditions. Thus we should observe the change in the malaria without being able to draw a very clear correlation curve between it and the weather.

Again, according to Walter [1908], afforestation has a marked effect on the number of rainy days. The great exhaustion of moisture from vegetation tends to increase the afternoon thunder showers which occur so frequently over tropical lands [but not seas] at certain seasons. It has considerable influence on crops, and doubtless helps to keep breeding-pools filled. Irrigated cultivation is evidently likely to have a large similar effect, especially with extensive irrigation works and with certain crops. High-class roads and railways tend to obstruct natural surface drainage and also to provide numerous breeding-pools in the "borrow-pits" along their route (section 57); and I have seen the undoubted effect of them in Sierra Leone, Lagos, Panama and Mauritius.
But whether the increase of total breeding surface produced by them is sufficiently large to modify the average Anopheline factor over a great area is another question. Probably irrigated cultivation has a larger effect. General increase of population may, by section 29 (7), increase the mosquito out­put out of proportion to the increase of the human population, by supplying more food to the female Anophelines, and diminution of prosperity may have the same result, by (12). Thus many things may modify the Anopheline factor; and as we possess no exact method of measuring mosquitoes it will always be difficult to decide how or why the factor has been changed, or if it has been changed at all.

(a) Changes in the carrying and living factors may occur as the result of a gradual predominance of certain species of Anophelines. As we now know, the fauna and flora of a country frequently change to a considerable extent. Those originally found in ocean islands, like Mauritius and the Seychelles, are apt to be almost swamped by imported species. Quite possibly, therefore, more 'virulent' species of Anophelines may gradually increase very greatly in certain areas, at least for a time under certain cycles of weather or with certain kinds of cultivation.

(c) Human immigration into certain areas, especially in connection with large planting, railway, mining or irrigation works, may tend to create foci of malaria (17); to enhance the local rate by the importation of cases or even of non-immunes; to increase the connection factors $a$ and $b$, by destitution or bad housing; or to raise the Anopheline output by additional food.

(d) The habits of the people may change in consequence of prosperity, famines, pestilences or increase of civilization. Thus they may use better houses, or houses of two storeys, or mosquito-nets, or glass windows. Or a larger proportion of medical men may practice among them; or quinine may
be more accessible; or they may abandon cultivation for trade or take to cities—and so on.

It will always be a very difficult matter to select the most probable factor. The final result will generally be due to the balance of all the forces, some pulling this way and some that. S. R. Christophers and C. A. Bentley have recently (1909) considered that a slow increase in certain Indian areas is due not so much to the Anopheline factor as to—that is, immigration in connection with large economic developments. Their paper is thoughtful, but, unfortunately, they do not deal with their subject quantitatively. They give us an estimate of the degree of the reputed epidemics, of the proportion of immigrants and of area occupied by them to total population and area, of their methods of enumerating the Anophelines, and, indeed, of comparing the effects of any of the possible factors. It is evident that immigration and allied factors may have some results, but it is necessary to calculate how much compared with those of other influences. Without some attempt at exact quantitative estimates, the scientific study of the diffusion of malaria is as impossible as that of the diffusion of heat. Many similar medical papers on the subject have the same deficiency.

21. Examples: Mauritius, Ismailia, Claira, British Africa—
In section 3 reasons were given for the opinion that malaria might have been comparatively scarce, or entirely absent, in Greece and Italy before the historic period, and that after about 550 B.C. it probably increased greatly in amount. This theorem can scarcely be proved, but I will now describe briefly the similar events which have occurred within the memory of living persons in Mauritius and likewise.

The island of Mauritius, situated about 550 miles (885 kilometres) east of Madagascar, and lying just within the southern tropic, covers an area of 705 square miles (1,825 square kilometres), rises to a height of about 600 metres in the centre, from which it slopes down more or less gradually
MALARIA IN THE COMMUNITY

The climate is the usual tropical marine climate, warm, equable and humid, and the vegetation is rich. Discovered in 1505, it was peopled by Dutch and then by French settlers, who were always introducing slaves from Africa and Madagascar. In 1810 it was taken by the British. The slaves were set free in 1834, and from next year onward an immense importation of coolie labour from India commenced and continued. Thus more than 20,000 coolies were introduced in each of the years 1843, 1854, 1858 and 1865, and in 1859 no less than 48,177 were imported. Quite certainly large numbers of these immigrants must have been infected with malaria, yet equally certainly, no endemic malaria occurred in the island all this time. I examined the point with the utmost care for the purposes of my Report to the Government, looked through existing returns and studied the voluminous evidence placed before a Commission of Enquiry. A. Davidson (1892) and many other writers have reached the same conclusion. In Saint-Pierre's classical novel Fial and Virginie (1719) no mention is made of malaria in the island. Dr Lorans, the late lamented Medical Director, who always lived there, informed me that there was none when he was a boy. At that time the planters and whites lived in houses scattered all over the country, and they and the British troops and officials lived entirely free from local infection. Relapses of malaria and other fevers such as relapsing fever were, of course, noted among the immigrants, but the malaria did not spread, though a few medical men suspected the existence of occasional sporadic endemic cases since (?) 1857. In 1865, however, a small outbreak commenced in a marshy district near the capital, Port Louis. Next year the epidemic reached the capital, and in 1866-1867 attained alarming proportions. It was like an epidemic of plague or cholera. One quarter of the inhabitants of Port Louis died from all causes in 1867, and 6,224 out of a population of 87,000 in one month (April). The whole
The death-rate of the island rose from 32,000 in 1866 to 120,000 in 1869, the total population being 350,000. The disease spread in two years all over the lower parts of the island, and has remained, and probably increased, ever since section 31.

In the sister island of Réunion, 133 miles distant, precisely similar results occurred at the same time. There also there had been no previous endemic malaria in spite of the introduction of slaves from Madagascar and of Indians from India.

How explain this extraordinary and terrible event which shattered existing notions about malaria? The present carrier is *P. annobi*, an African, not an Indian mosquito. If it had existed in the islands in large numbers, the epidemic would have commenced long previously—certainly with the beginning of the enormous Indian immigration, thirty years before its actual commencement. If it had existed in small numbers, below the endemic limit, it might still have spread the disease to some extent, according to the reasoning in [21]; but most authors denied that this occurred at all before 1865. Moreover, on both those suppositions, the chances are that the epidemic would not have commenced simultaneously in both islands, especially because the Indian immigration into Mauritius was much greater than that into Réunion. I can only conclude, therefore, that *P. annobi* was introduced from Africa or Madagascar simultaneously into both islands, probably by the same vessel, a year or two before the epidemic; that it spread rapidly and soon multiplied over the endemic limit; and that from this point the success and ultimate permanence of the malarial invasion was assured.

Of course the inhabitants would not be able to distinguish the new carrier among the swarms of tropical mosquitoes already present, and there appears to be no reason why, after being once introduced, it should not have reached the endemic limit of numbers in a year or two. This therefore appears to be wholly a case of the Anopheline factor. The
human factors had been present for at least thirty years without causing the disease.

A similar case is that of Damattie (section 53). Situated on the Suez Canal in the desert, it remained free from malaria until the fresh water canal was completed in 1877, when malaria appeared almost immediately. Since then the disease continued to increase with fluctuations, until it was banished in 1900 by proper mosquito reduction. Here again the outbreak was probably due almost entirely to the Ampitama factor.

A more difficult case is that of an outbreak in the neighbourhood of Eltiert Rish in Muttinah (section 79 (1) map), already frequently mentioned. This marsh existed on a plain 1,850 ft (547 metres) above sea-level, and the epidemic is described in my Report [1908] by Dr de Chazal who had been practising in the neighbourhood since 1899, and by myself, and also by Major Fowler [1909]. The history is as follows:

Before 1905 Dr de Chazal, who lived not far from the marsh, had observed a few cases of malaria, but only among Indians. In that year, however, cases began to occur among well-to-do people living in the neighbourhood, and the epidemic now developed rapidly. The cases at the neighbouring dispensaries were as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1905</td>
<td>110</td>
</tr>
<tr>
<td>1906</td>
<td>143</td>
</tr>
<tr>
<td>1907</td>
<td>1,127</td>
</tr>
</tbody>
</table>

and similar rises in the cases of malaria at seven other dispensaries, situated far away, also occurred. In 1906 the British soldiers in barracks (see subsection 1) began to be affected. In 1908 Major Fowler and I witnessed an epidemic of seventy-one cases in January among these troops, and on making a house-to-house visitation, found a spleen rate of 241, 335, and an average spleen of 412 among the Indian children living round the marsh. The disease was being carried by P. cos/i/is, which our "moustiquiers" found
with considerable difficulty, and not by *M. maculipennis* which abounded round the marsh. The marsh was now drained by the Government; quinine was simultaneously distributed in the houses by themselves and a dispensary; and the epidemic ceased.

We explain it? The marsh had been there as long as any one could remember, and *P. ovatus*, though it prefers raised, had probably been breeding in it in small numbers all the time. Indians as well as the richer classes had been living near at hand, and imported cases had certainly been common. Why, then, did not the epidemic commence before? Up to 1843 the population round the marsh had been comparatively scarce, but in that year a great increase of Indians took place owing to the arrival of a regiment of Sepoys, and many of those Indians built huts close to the marsh waters. How, then, might be a case of creation of a focus of high endemicity; but still I find it difficult to explain the facts without supposing an increase in *P. ovatus*, per se, with that of the human population. The case is most probably explained by an increase due to more abundant food in the new huts built close to the marsh, according to sections 29, 121 and 3019 and 122, and possibly by an increase in the biting factor, due to the growth of the village nearer to the marsh.

The disappearance of malaria from Britain has been ably described by G. W. F. Nuttall, L. Cobbett and T. Strangeways-Pigg [1901]. The observers made a careful study of the former distribution of the disease in Britain, and of the present distribution of the *Anopheles*. The two coincided to some extent—that is, the malaria was within the *Anopheles* area, but not so extensive. The disease, formerly severe, began to decline early last century, but still lingered on until about 1850.

I was "clinical clerk" in St Bartholomew's Hospital in 1871, to a woman with greatly enlarged spleen and characteristic fever, who lived in the Fen Country and had never been out of England. Since that time endemic malaria has entirely
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 vanished from Britain, with the exception of two cases among soldiers (footnote, section 14).

The three British Anophelines are A. maculipennis, A. albicollis and A. nigripes. They are all capable of carrying malaria, but Theobald thinks that the first will not bite man in Britain. The authors conclude that the disappearance of malaria has been due (a) to reduction of Anophelines by drainage; (b) to reduction of population by emigration; and (c) to the use of quinine. I think that (b) is not sound. The disappearance is almost certainly due to the reduction of the Anopheline factor by drainage below the endemic limit, even in the Fen Country, and also to enhancement of the recovery factor by the more general use of quinine. I wonder, however, whether there has been any change in climate and whether glass windows have been used more since the beginning of last century.

Many other examples might be cited, but I doubt if the reader will wish to consider them for himself.

(125) Possible errors in the study of endemicity—One is very apt to find the local endemicity too high in comparison with the local number of Anophelines to be found in houses. In 1907, in an intensely infected plantation near Ootacamund, India, I found during several visits only one Anopheline (the first I ever saw), although I searched the houses myself and offered the people rewards—and this was at the height of the malaria season. In fact there were so few mosquitoes of any kind that I began to doubt the whole mosquito theory (just before the discovery of the zygotes). The local carriers were probably "wild" mosquitoes which I did not know how to look for; or else I may have missed the principal hatching-out season. At Clairfond ten trained "mosquitoes" could procure only a few P. relictus every night. We must never assume,

1 Sir Clifford Allbutt tells me that he saw numerous cases in Cambridge in 1860. Nuttall, Cobbett and Strangeways verified a case at Norwich in 1898 (1911, p. 35).
without clear proof, that the number of insects seen or caught during a few hours' or days' search affords any exact measure of the number actually present during that period—still less of the number which may be present at other periods.

It is often observed that the malaria ratio is high where there happen to be little breeding-sites—what "dry" places seem often to be more malarious than "wet" ones. But we have no right to assume that the carriers always breed more in the deep or permanent pools which constitute "water-laying" than in the shallow, evanescent rain-pools which are often the only water found in the drier areas. The latter may perhaps give a much larger output of the proper season than the former can yield all the year round (sections 29, 30, and 31). In some cases the Anopheline factor is probably truly below what we might expect from the malaria ratio; but such cases may be due to extraneous infection (19), or to immigration from neighbouring areas of high endemicity (20, 21).

Statements are frequently made to the effect that though the number of Anophelines in a locality is large the malaria ratio is small—as, for instance, the case reported by Celli (1920). Here again we must not assume that the number of Anophelines actually found during a few days is an exact measure of those existing all the year round. We have, perhaps, done the counting just at the moment when the insects happened to abound. Or, in comparing two localities, we may have been concerned with a domestic species or variety in the locality where the insects appeared to be more numerous, and a wild species or variety in the other locality. Even where it is proved by continued observation that the Anophelines do really average a high figure where there is little malaria, this will merely suggest that some of the other factors are unsuitable; for example, the local insects may belong to an immune strain. Thus we have never succeeded in infecting the A. maculipennis round Liverpool from infected sailors.
In fact those who pretend to study the correlation between the Anopheline factor and the malaria rate are very prone to make two mistakes: (a) they often fail to consider deeply enough the principles involved, and (b) they are apt to have starting "discoveries" on quite insufficient random-sampling—an error into which, according to Professor Karl Pearson, medical men frequently fall. So far as the human reason enables us to judge, there must be some correlation between the two quantities. When, therefore, we are told—as we frequently are, especially in India—that so-and-so has not observed any such correlation, we naturally look for the detailed figures of his investigations; and when we find, in place of these, mere statements of opinions and impressions, we naturally infer that it is not the principles which are worthless, but the observations. A person who thinks to settle such difficult questions merely by running from village to village, catching a few Anophelines and examining a few people, can have little knowledge of the nature of scientific evidence. To yield any worthy results at all, the inquiry would demand the most careful and continuous study of all the factors concerned (sections 29 (4), and 31).

A mistake frequently made is to suppose that there must be some correlation between the number of Anophelines existing on a given day and the total percentage of infected persons. But the former will tend to influence only the inoculation rate of the future. The total percentage of infected persons will depend upon past factors which may no longer exist. They are often, or generally, connected, but not necessarily always so.

Equal errors may be made regarding the measurement of human malaria. For example, the disease is often supposed to be specially prevalent among soldiers, coolies or prisoners; but this may be merely a statistical error, due to the fact that these classes are under more careful supervision than the general public is.

(21). I have attempted to examine as carefully as possible
the principal factors concerned in the spread of malaria, but may have overlooked several of importance. The effect of immunity, both among men and Anopheles, deserves much closer study. So also do many questions connected with difference of species of the parasites. It is by no means certain that immunity against one species confers much or any against another. If this is the case, many epidemics may be caused merely by the entry of a species not hitherto prevalent in a locality, and the simultaneous prevalence of all three species may lead to a much more serious fever rate. Koch observed [1900] that comparative immunity against quartan seems to have little effect against the other parasites, but I am not sure that reaction against an evident invasion in a person will have any such effect against a new infection even by the same species. The effect on the local malaria rate of diversion of marshy areas by should be similar to that of drainage, and must not be forgotten. Conversely, the effect of approximation to a marsh, as when people come and settle near one (for example, the Clairfield outbreak just described), should be similar to the effect of increase of marsh. Obviously it will come to the same thing if we bring a marsh close to human habitations, or bring human habitations close to a marsh.

31. The Measurement of Malaria.—In section 26 I gave definitions of the terms malaria rate, endemicity, and inoculation rate. We have now to consider how these and other estimates can best be obtained for a given population inhabiting a given area. Note to begin with that we can never obtain any such rates exactly; and also that the degree of approximation to the truth must always depend on the amount of time and labour we have to spare for the task.

Our estimates may be of two kinds, actual or comparative. Comparative estimates are those which seek to compare the
proportion of infected persons in the same locality at different
times, or in different localities at the same time. It may
often be much easier to obtain comparative than actual
estimates.

Let us consider first the different possible methods, and
then the respective values of them.

1. The parasite rate and index.—By malaria rate or ratio
I mean the percentage or proportion of people who really
contain living plasmodia at some given moment—not those
who show symptoms. By parasite rate I mean the same
thing. Now in section 13 (8) and (9) it was shown that
an average man contained about 300,000 c.c.m. of blood,
and that a quarter of an hour is required to examine
1 c.c.m. under the microscope. Thus by that time
we can search only 1 c.c.m. of a man's blood. In other
words, if there are less than 150,000,000 parasites in the
patient's blood the chances are that we may not find one,
even after a quarter of an hour's search. Hence we can never
hope to ascertain with certainty whether a single patient does
or does not contain plasmodia, and can therefore certainly
never discover the actual parasite rate of any number of people.

By parasite index I mean the percentage of persons in
whose blood plasmodia are found after fifteen minutes' search
—that is, of persons who contain more than about 50 plasmodia
per 1 c.c.m. of blood. To ascertain even this is a laborious task, requiring
for 100 people twenty-five hours' continuous work.

Obviously the parasite index must always be less than the
parasite rate. What ratio will the latter bear to the
former? We do not know. Out of 100 infected persons
perhaps only 60 or 70 may contain more than 50 plasmodia
per 1 c.c.m. of blood at a given moment. But this is a mere
guess, and no accurate studies have been made on the point.

The ratio certainly varies largely, but as we do not know it
with certainty, the parasite index gives no exact information.
regarding the actual parasite rate. It gives valuable information, however, on one point. Every person in whom parasites are found is certainly infected. Hence the parasite index gives at least the minimum possible percentage of infected persons—that is, we know that the actual parasite rate cannot be less than the parasite index.

For comparative estimates the parasite index is still more useful, because in them we deal only with ratios from time to time or from place to place. Thus it has varied from say 20 to 55 in two large aggregates of persons examined, we may infer that the actual parasite rate has varied to a similar amount. We do not know that the actual parasite rate was, with the parasite index either of 20 or of 55, but we conclude that its variation has been some little parallel, similar—that is, from 20 to 55.

As originally observed by Koch and Stephens and Christopher, confirmed by Ziemann, Polno, Amott, and Dutton and many others, the parasite index varies greatly according to age, being generally highest in children. Hence comparative estimates must be based on a study of persons of the same age. Year, season, treatment, and social status seem also to have considerable effect.

The method is open to several sources of fallacy. The skill of the observer may make a difference of say 20% or more in the results obtained; and the time employed in the search for plasmodia is very important. In 1966 I obtained a number of slides of blood from Greek children, and since then these slides have frequently been given for study to the classes of the Liverpool School of Tropical Medicine. On every occasion that this has been done, one or more of the students have discovered parasites in specimens in which they had not been previously found! In making exact comparative estimates it is therefore necessary to employ observers of the same skill, and to fix the time during which the search must be made.
But the principal weakness of the method is due to the fact that, owing to the labour involved, only a comparatively small number of people can be examined—so that the error of random sampling is likely to be very large. Thus, suppose that we have examined 50 specimens for 15 minutes each, costing 125 hours' work exclusive of collecting and staining, and have found plasmodia in 25 specimens, we have no right to infer that the parasitic index of all the people in the locality will be 50%. The chances are, by Poisson's formula (8), that if we examine another 50 persons we may find parasites in any proportion of them from 30% to 70%—the error being 20%.

Thus, if the same observer, using precisely the same method, examines 50 different persons on two occasions, and finds 24 infected on the first occasion and 33 infected on the second occasion, he still has no right to assume that the actual parasite rate (i.e., the malaria rate) of the locality has risen between the two examinations.

The method is probably capable of much improvement by quicker means of microscopic diagnosis (sections 6, 7, 8).

(21) The spleen rate and index.—This method has been in use for a long time. We know that the spleen enlarges sufficiently to be detected by palpation in a considerable proportion of infected persons. Such enlargement is discoverable with certainty and in a few seconds by the fingers pressed under the ribs of the left side, and any one—hospital assistants, nurses and laity—can detect it. The persons to be examined are passed in a line before the examiner, while another person records the results; and with good management 100 people can be thus inspected in an hour. Or else we can do the work by house-to-house inspection. In section 23 I gave the results of a "spleen census" of 31,022 children in Mauritius, and of 92,258 children in Ceylon—so that very large numbers of people can be studied by this method. It is open to the following defects:

(a) The enlargement may be so slight in a small proportion
of cases, especially early infections, that it may be overlooked in them if we use palpation only. Generally, however, there is fever, or a history of recent fever, in such cases.

The spleen of healthy infants is sometimes so easily palpable that the unskilled observer may think that it is enlarged.

(a) Not all infected persons show palpable splenomegaly.
(b) Not all splenomegaly persons are necessarily infected.
(c) Other diseases, such as hæmorrhagia and various anemias, cause splenomegaly (section 12), but the former is limited to certain tracts of country, and the latter are too scarce to affect large statistics. Generally speaking, widespread splenomegaly is due to malaria.

The advantages of the method are:
(a) That the enlargement can be detected practically with certainty, and in a few seconds by almost any one.
(b) That this method can be applied with little trouble to enormous numbers of people, thus practically avoiding the error of random sampling.

I have never known rupture of spleen to follow palpation; but the possibility of this must be remembered.

We must note that a smaller degree of splenic enlargement can be detected by percussion (as practiced by medical men) than merely by palpation. By the former method we can nearly always detect some enlargement in malaria. Thayer [1898] claims that it always occurs. Mannsberg says (1905) that out of 132 cases of different types, "ostearthritis omitted," he found it in all but one case—in 131 cases (114.2% of total) by percussion alone, and in 156 (90%) by palpation also. Thus the finer art of percussion added nearly one-eighth more to the number of cases disclosed by palpation. Lateran agrees as to the frequency of this symptom, but other authors give lower
percentages. It is probably often a question of care in examination. Among sailors treated at the Royal Southern Hospital of Liverpool, palpable enlargement is not very frequent. Many writers give percentages without actual—that is, nearly worthless—figures. L. M. Hope (1903), in a study of 1724 cases, microscopically verified at Pabna, Northern Bengal, states that in 374, or 22%, the spleen was not palpable; but she does not state whether the remaining cases were studied by percussion. In 122 Greek children examined by me (4), the spleen was palpable in 46, and parasites were found in 12 which showed no enlargement (by palpation only). Probably careful percussion would have disclosed some enlargement in all of these cases. On the whole, then, I think we should conclude that some degree of splenic enlargement probably exists in 55-100% of all persons infected with malaria; but that the enlargement is great enough to be palpable only in about 75-90%.

The reader should note this difference between enlargement detectable by palpation or by percussion only. In public health work, which demands the examination of large numbers of people in order to avoid error of random sampling, careful percussion is not generally practicable, or, at least, practised. Thus by the term 'splenic index' I generally mean the percentage of persons in whom enlargement is detectable by palpation only.

In order to determine the spleen size accurately, it is necessary to use careful percussion on all persons in whom no enlargement has been found by palpation. If such persons are numerous this may add considerably to the time required for the investigation—say two or three minutes for each person. Another important point has to be considered. We have no right to assume that the parasites are still present in all the cases of enlarged spleen, especially in the older cases with large chronic splenomegaly. Such cases may have become parasite-free by establishment of natural immunity; but we can never know in how many the parasite have absolutely vanished, or
have only declined in numbers below the limit at which we can readily find them.

In what proportion of persons with enlarged spleen are there no plasmodia at all? It is impossible to say; but we may give 20%, a rough conjectural estimate.

Suppose, then, that 20% of persons with parasites have no palpable enlargement of the spleen, and that 20% of those with palpable enlargement of the spleen have no parasites—or, at any rate, that the two percentages, whatever they may be, are about equal. It then follows that the palpable spleen rate, or spleenic index, will give a nearly exact measure of the percentage of infected persons—that is, of the actual malaria rate of the locality. But at present this theorem, which would be of great practical importance, is based only on conjectural estimates.

Lastly, we must note that the spleenic index is probably modified considerably by local conditions, quinine, and the age of the people examined (sections 22 and 31).

35. Combined parasite index and spleenic index.—If we have time we can use the parasite index and spleenic index combined. The people should be divided into four classes: (a) those without enlarged spleen or detectable parasites; (b) those with both; and (c) and (d) those with one but not the other. Thus, out of 102 children examined in Greece, we found—

<table>
<thead>
<tr>
<th>Spleenic Index</th>
<th>Parasite Index</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
<td>27</td>
</tr>
<tr>
<td>None</td>
<td>Palpable</td>
<td>7</td>
</tr>
<tr>
<td>Palpable</td>
<td>None</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>Palpable</td>
<td>No plasmodia</td>
<td>1</td>
</tr>
<tr>
<td>Palpable</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>Palpable</td>
<td>Palpable</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>Palpable</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>52</td>
</tr>
</tbody>
</table>

Note if we use the term endemic index (section 26) to denote the percentage of persons in whom malaria is diagnosed by any method, then the endemic index of Mouli at that time was 90/62 = 0.435, and of Mali was 20/40 = 0.50. Provided that we know that the splenomegaly is due only to malaria and also have time to work out the parasite index, this combined method...
is obviously more exact than either method by itself. Thus in both these villages together, the parasite index by itself was only $33/102 = 32\%$, and the spleen index by itself only $48/102 = 47\%$. While the combined methods give a general endemic index of $60/102 = 59\%$.

It is important to note that in this example, while the cases with enlarged spleen numbered 48, those with parasites but without enlarged spleen, numbered 12, or $\frac{1}{4}$ of the spleen cases. If this proportion applies generally, the endemic index will be found by adding $25\%$ to the spleen cases. (This figure is, however, too high by the results of Macalister and Hope just quoted.)

Again, the cases with parasites numbered 33, while those with spleen but without parasites numbered 27, or $\frac{9}{11}$ of the parasite cases. If this proportion holds generally, the endemic index will be found by adding $8\%$ to the parasite cases.

It would thus seem that the spleen index is much nearer the truth than the parasite index—provided that the splenomegaly is really due only to the malaria.

Lastly, we observe that the figures both at Moulik and at Mazi are too small to enable us to make exact comparative estimates of the malaria rate of each village; and we should probably have done better if we had abandoned the parasite index and had spent the time at our disposal in examining the spleen of every person in the villages. Moulik, on the plain of Kopais, contained 350 people; and Mazi, several hundred feet above the plain, contained 515 people. The figures were obtained in May to June [1906], at the beginning of the malaria season.

The number of persons with parasites but without splenomegaly seems to me an important figure, because such cases are probably due to recent infections, before the spleen has had time to become enlarged—especially in children. There were no less than $12/102 = 11.8\%$ of such in these two villages,
suggesting that the spring infections had already commenced. The weather was hot, and *A. maculipennis* plentiful.

44. **Average spleen and average enlarged spleen.**—By the parasite index and spleen index, or by both combined, we attempt to estimate the percentage of infected persons in a locality; but further information can be obtained by recording the degree of enlargement found. For this purpose I suggested in Mauritius (1908) a figure which I call the *average spleen* (section 23). The observer notes whether the size of the spleen, as roughly estimated by palpation, is unity, or about three times, six times or nine times the normal size—these sizes being called normal, or small, medium or great enlargements. He then multiplies the number of persons found to possess each class of enlargement by 1, 3, 6, or 9 as the case may be, adds the products together, and divides by the total number of persons examined. Thus in Mauritius we found, out of 30,137 children of fifteen years and under:

<table>
<thead>
<tr>
<th>Class of Enlargement</th>
<th>Number of Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal spleens</td>
<td>14,711</td>
</tr>
<tr>
<td>Small enlargements</td>
<td>4,381</td>
</tr>
<tr>
<td>Medium enlargements</td>
<td>3,047</td>
</tr>
<tr>
<td>Great enlargements</td>
<td>2,566</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30,137</td>
</tr>
</tbody>
</table>

Thus the *average spleen* for children in the island works out at 2.54 times the normal size.

Another figure, which I call the *average enlarged spleen*, is found in the same manner, but without considering the normal spleens; that is, multiply the small enlargements by 3, the medium enlargements by 6, the great enlargements by 9, add the results, and divide by the total number with enlarged spleen. In the above example, the *average enlarged spleen* was 5.48. Obviously, according to the rough standards proposed, this figure must always lie between 3 and 9.

These estimates require a little more time to obtain than the simple spleen index, and should generally be attempted only by medical men. I think that one minute a person will
The information given is more detailed, but also more open to error, since different observers may have different ideas as to what constitute small, medium or great enlargement respectively.

The degree of enlargement probably depends considerably upon the factors given in section 22—racial, social and climatic factors, and age and treatment of the sick. That is, two populations with the same actual proportion of infected persons may have different average enlarged spleens, the difference depending on these factors.

The average spleen depends, not only on the degree of enlargement, but also on the proportion of infected persons (general malaria rate), and may be looked upon as an index of the average amount of illness caused by malaria in the community. The average enlarged spleen indicates only the degree of enlargement where it exists. Several useful deductions may be drawn from the figures. Thus numerous small enlargements would tend to indicate many recent infections; and numerous large ones with few small ones, a past epidemic.

The comparative figures for Mauritius may be taken for a standard, as malaria has prevailed constantly there since 1866. The species of parasite may have considerable influence on the degrees of enlargement. C. F. Craig [1909] thinks that the malignant parasites produce most enlargement; but L. M. Hope [1904] found that in 43 great enlargements malignant parasites occurred in 10, benign tertian in 9, and quartan in 32 (some of the infections being mixed).

The study of the splenic enlargement, so important for public health work, has been curiously neglected in medical literature.

(1) The fever rate and index.—By fever rate (daily, monthly, annual) I mean the percentage of persons who really have malarial fever during a given period; by fever index, I mean the percentage of those who have been ascertained to have it. The index must be always lower than the rate. Even
with soldiers, gaol prisoners and indentured coolies the most careful supervision would be required to detect all the slighter cases. Among troops the bad custom still remains of entering in the books only the more severe cases—which are said to be admitted to hospital, while the slighter cases are only detained. This quite falsifies the malaria statistics, and is due only to bad administration. Besides this, many soldiers disdain to come to hospital for slight attacks. If this is the case among these classes, then we can imagine how difficult it would be to estimate the fever rate among a large civil population.

If we could do so, however, we should have a fairly exact measure of the malaria rate—since every infected person probably suffers more or less from illness during at least some part of his infection. But we have no measure of the ratio between the rate and the index. Probably the former is often two or three times the latter, even in the case of troops.

But, while it gives little exact information regarding the actual malaria rate, the fever index is still useful. The admissions into military hospitals, civil hospitals and hospitals of gaols and plantations, are generally fairly correctly diagnosed by medical men, and give some idea of the great amount of sickness caused by the disease. The same is true of the large number of attendances for malaria in out-patient departments and dispensaries. The figures are valuable for comparative estimates of variation from time to time or place to place.

Both for admissions and attendances, the actual numbers of patients admitted or attending any hospital are not very useful, as they may be influenced by the popularity or accessibility of the institution; but the ratio of admissions or attendances for malaria, compared with those for all causes, is always important, not only for comparative estimates, but because it shows the relative importance of malaria compared with all other diseases. It gives us some basis for fixing the proportion of the public funds which should be expended on
the prevention of the former, according to the general sanitary principle enunciated in section 38 (4), namely, that that proportion should depend on the relative importance of the various diseases.

For example, in Mauritius during the seven years 1900-1906 we had the following figures—

- Average population: 344,676 a year.
- Average admissions for all causes: 42,964.
- Average admissions for malaria alone: 4,338.

Thus malaria caused nearly one-quarter (23.7%) of the total admissions. Moreover, in the year 1907 alone there were 76,102 admissions for all causes at all the hospitals and dispensaries in the island, and of these 28,294, or 37.1%, were reported as due to malaria.

This is an example of the general law that the attendances for malaria are greater than the admissions (in comparison to total attendances and admissions). Obviously only the more severe cases of fever seek admission into hospital, and a much larger proportion of all malaria cases content themselves with mere attendance for advice and medicine.

In India in 1901 (before quinine was much given), out of 300,847 troops and prisoners 108,860, or 36.2%, were admitted for malarial fevers; and these admissions constituted, according to the official figures, 37.2% of the admissions for all causes. I take this year at random; and it will be seen on inspection of similar statistics in most tropical countries that similar figures hold roughly from place to place and time to time in most of them.

As a very broad general rule we may state that in most, or at least many, malarious countries about one-third of the total population considered require medical treatment for malaria every year; and also that malaria is responsible for about one-third of the total attendances at hospitals and dispensaries. Or, to be still more general, we may put both these ratios at something between one-quarter and one-half.
Of course, errors in diagnosis vitiate the figures to some extent. Thus many cases of fever are not malarious at all, but may simply be cleared under that heading by careless or overworked observers. The symptoms of the disease are, however, so well marked that I doubt whether the total error involved in this manner is really very large—say over 50.

On the other hand, the error of random sampling for the purpose of obtaining a parasite index is often very much greater.

M. Watson (section 57) has used hospital statistics well for showing the comparative fall of the malarial rate in drained areas. While the admissions from the drained areas fell rapidly, those from the surrounding undrained territories continued as before.

The clinical thermometer may be used more than it is for estimating the endemic index. It could easily be employed together with examination of the blood and the spleen.

The constantly sick rate and index—By these terms we mean the average proportion of people who are actually ill with malarial fever at a given moment—or who are found to be ill (index). Thus in India in 1901, out of 60,938 European troops, on the average 605, or 1.05%, were always ill with malaria—that is, almost the effective strength of a whole regiment. In Mauritius, Dr Bolton, Medical Officer of the Immigration Department, estimated for me that during the malaria season in the most malarious sugar plantations as many as 20% of the total male adult population may be sick from malaria alone on one day. As the malaria season is often also the busiest agricultural season, such a figure means an enormous loss of labour.

These estimates are important because they afford some measure of the economic loss due to the disease. Thus in India in 1901 the European troops lost 605 x 365 x 243,000 working days during the year, besides loss due to death and invaliding, and loss of capacity for war. But as a rule the estimates can...
be obtained only for troops, coolies of factories and plantations, and prisoners. For the general population we can have no definite figures, and can only calculate them on the basis of the former classes.

The average duration of a case can be obtained from the constantly sick index (or vice versa) from the following formula:

\[ \text{Admissions} \times \text{average duration} = \text{constantly sick} \times \text{days in year}. \]

In India the average duration of a case of intermittent fever among European troops is about two weeks, and of remittent fever about four weeks; but this, of course, means only the residence of the men in hospital, and takes no note of relapses. The figures will be found in Table IV of the Indian statistics.

(7). Malarial death-rate.—In most malarious countries medical certificates giving the cause of death are not demanded. Hence in such countries the public statistics are not reliable as regards the cause of the mortality—that is, we can have no confidence in the number of deaths attributed to malaria in the tables. We can often, however, obtain valuable information by calculation from the figures of general mortality; but this subject requires to be dealt with separately (section 32).

(8). Random sampling.—Nothing has caused more mistakes in the literature of malaria, and indeed of most medical and sanitary subjects, than ignorance of the great error in reasoning which may be caused by insufficient random sampling.

Suppose that we desire to ascertain some general law regarding a large number of objects. Then the only exact way to ascertain the law would be to examine all the objects. Suppose, however, that we have no time to do this; then we must content ourselves with the attempt to ascertain the law approximately by examining samples. We must take the samples quite at random, and must examine enough of them. Obviously, if the total number of objects is large, we shall obtain no correct deduction by examining only one, two,
three... of them. The more of them we examine the nearer we shall come to the exact truth.

Suppose, for example, that we wish to ascertain the proportion of leucocytes in a patient which belong to the mononuclear variety. We may be very far from the truth if we examine only two or three leucocytes; nearer if we examine twenty or thirty, or two or three hundred, and still nearer if we examine two or three thousand; but we can obtain the exact truth with certainty only if we examine all the leucocytes in his body.

So also if we wish to know the parasite index in a locality—that is, the percentage of people in whom plasmodia can be found after, say, quarter of an hour’s search. If we examine only two or three persons we may be very far from the truth; we shall come nearer and nearer to the truth by examining more and more of the people; but we can obtain the exact truth with certainty only by examining every person in the locality.

If we have time to examine only some of the people we can obtain only an approximation to the truth. It is a gross error in science, and yet one which is very frequently made, to suppose that this approximation is the truth itself. Take for example the case mentioned in (i) above. Suppose that there are 10,000 people in a place, and that out of 50 people examined we have found the parasites in 25. Then we are quite truthful when we say that the parasite index of the 50 people examined is 50%, but if we presume to argue, on the strength of this small random sampling, that the parasite index of the whole locality, containing 10,000 people, is 50%, we make a gross scientific error, and say what may be absolutely untrue—what, in fact, may be not even near the truth. Similarly, if we try to estimate the number of Atrachelus in this locality by counting them in only a few houses we may make another error equally gross. Lastly, if, after making two such errors, we next proceed to argue that
there was no relation between the parasite index and the number of Anophelines in the locality, we may perhaps come to a wrong conclusion; but, whether our conclusion is right or wrong, we shall certainly convict ourselves—well, not exactly of scientific competence.

This error is frequently made tacitly in medical literature by recording only percentages, without giving the actual number of objects examined. For example, an observer says that 40% of a patient's leucocytes were mononuclears, or that 50% of the people in a place showed malaria, without stating how many total leucocytes or people were examined. Such statements have no meaning whatever—except that the man who makes them is ignorant of this simple law of reasoning. A reader cannot judge the value of a writer's deductions unless he knows the actual facts from which those deductions were drawn. Where a writer merely gives a percentage in this manner, we cannot be sure whether he has not deduced it from a study of only a few objects. But we are sure of something else, namely, that he is not acquainted with the methods of accurate reasoning, and are therefore forced to doubt the value of all his deductions. It is necessary to make these somewhat severe remarks, if only in the hope of saving the waste, occasioned by this common mistake, of otherwise excellent work.

The reader will now remark that it is impossible to examine all the leucocytes in a patient's body, or all the people in a large district. How many must we examine in order to approach sufficiently near to the truth? This question belongs to the domain of statistical science and cannot be discussed at length here; but it is advisable to give the well-known Poisson formula for statistical error, with an addition made by Professor Karl Pearson, the amended formula being particularly useful for the measurement of malaria.

Let \( N \) be the total number of objects, such as all the leucocytes in a patient's body or all the people in the locality.
Error of random sampling. Let \( n \) be the number of these actually examined (say 200 leucocytes or persons); and let \( p \) be the number of these found during the examination to belong to a special class—suppose that \( p = 100 \) mononuclear leucocytes or plasmodia found to contain plasmodia. Then \( p/n \) will be the corresponding ratio among the objects examined—that is, it will be \( 1/2 \), or \( 50\% \), in the examples referred to. But we have no right to infer that the same ratio will hold for all the \( N \) objects under consideration. Let \( e \) denote what is called the error, and \( e/n \) the proportion of error. Then by the Poisson distribution formula,

\[
e^n = \frac{N^m}{m!} e^{-\lambda},
\]

Examining this formula, we shall see that when \( n = N \), that is, when we examine all the objects under consideration, the factor \( (n-1)\cdots(N-1)/n! \) and the whole error vanishes; that is, we obtain the exact truth. But if \( n \) is small compared with \( N \), this factor, and therefore the error, becomes larger. If \( N \) is very great, as when we are considering all the leucocytes in a patient or all the people in a large district, the same factor approximates to unity, making the error large—unless \( n \) can be correspondingly increased.

Thus, if out of 200 leucocytes examined, 100 are found to be mononuclear, then, since \( N \) is very large, \((n-1)\cdots(N-1)/n! \approx 0\), so that \( e^n = \sqrt{100 \times 10} \). That is, the error is 10%. We might have inferred, after finding 100 mononuclears out of 200 leucocytes examined, that the same proportion (50\% mononuclears) would have held for all the leucocytes in the patient's body. But we have no justification for this assumption. The probability is that if we examine another 200 leucocytes, the proportion in this second batch may be anything between 50\% ± 10\% and 50\% ± 10\%, that is, may vary from 60\% to 40\%. All that we can infer, then, from the small sample of leucocytes examined by us, as to the exact truth regarding all the leucocytes in...
MALARIA IN THE COMMUNITY

The patient, is that the percentage of mononuclears probably lies between 60% and 40%—a very different thing from the 50% which we might, ignorantly, have assumed to be the proportion.

Now suppose that we have to deal with a village of 800 people, and that we have examined 200 for plasmodia and have found these in 100 of them. Here the factor \( \frac{1 - (n-1)/(N-1)}{(n-1)} \approx \frac{1}{4} \), and the other factor = 10 as before. Hence \( \frac{x}{\sqrt{n}} = 5\sqrt{2} = 8.5 \). Thus, while the parasite index of the 200 people actually examined is 50%, that of the 800 people in the village may be anything from 50 + 8.5% to 50 - 8.5%, that is, from 58.5% to 41.5%.

Suppose, however, that in the same village we had examined only 40 persons (as a recent Indian writer recommends) and had found plasmodia in 10. Then the percentage of error \( \frac{10}{40} \sqrt{2} = 21.8 \), and the parasite index of the village will not be 50%, as the unwary student might imagine, but anything between 71.8% and 28.2%—a very ambiguous result. Yet we are often asked to accept important theories on figures like these.

The following square roots may be useful:

<table>
<thead>
<tr>
<th>Square root of 2 = 1.41</th>
<th>Square root of 3 = 1.73</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 = 1.73</td>
<td>10 = 3.160</td>
</tr>
<tr>
<td>5 = 2.24</td>
<td>12 = 3.464</td>
</tr>
<tr>
<td>6 = 2.44</td>
<td>13 = 3.600</td>
</tr>
<tr>
<td>7 = 2.65</td>
<td>14 = 3.741</td>
</tr>
<tr>
<td>8 = 2.83</td>
<td>15 = 3.872</td>
</tr>
<tr>
<td>9 = 3.00</td>
<td>16 = 4.000</td>
</tr>
<tr>
<td>10 = 3.16</td>
<td>17 = 4.123</td>
</tr>
<tr>
<td>11 = 3.32</td>
<td>18 = 4.243</td>
</tr>
<tr>
<td>12 = 3.46</td>
<td>19 = 4.360</td>
</tr>
<tr>
<td>13 = 3.60</td>
<td>20 = 4.472</td>
</tr>
</tbody>
</table>

The error tends to be larger when the percentage of objects belonging to the particular class is near 50% of the total number of objects examined, than when it is a low or high percentage. We must therefore examine, for example, more leucocytes to obtain the percentage of mononuclears than to obtain that of eosinophiles; and more people if the parasite
Variation of the malaria index according to age.—It is now generally accepted that amongst the natives of a permanently malarious locality the signs of infection—parasites, fever, enlarged spleen—are generally much more frequently found in children than in adults. From this we infer that the individual can acquire natural immunity against the disease.

So far as I can ascertain, this fundamental law was first discovered and stated by C. W. Daniels as the result of his study of a large number of autopsies in British Guiana (1895). He found that the frequency, not only of simple enlargement of the spleen, but also of the malarial pigmentation of the organ, varied from age to age. Both enlargement and pigmentation were absent in the bodies of infants less than one month of age; became more and more frequent in bodies of children up to five years of age, in about 80\% of whom they occurred; and then became progressively less frequent with advancing age. These results were obtained from 1,289 autopsies on natives of the colony or of other malarious places—mostly negroes and East Indians. But different figures were recorded from 205 autopsies on persons, chiefly negroes, who were born in non-malarious places, and had come to the colony in early adult life. In nearly all of these the symptoms occurred shortly after arrival, and then fell in frequency with age, but never to so low a figure as in the case of the natives. The following are the curves for the negroes and East Indians. (See page 236).

Daniels remarked: "It is, I think, clear from these figures that malaria is, amongst those exposed (to it) from childhood, a disease of early life. . . . In adult life, amongst them, it is rare; whilst amongst persons of the same race, but not exposed in childhood, it is common in adult life. This, it seems to me, can point to only one conclusion, viz.: that immunity is acquired by a class (that is, natives) in the course
of exposure to the infection in this district for some twenty years; and, from the evidence of its frequency (evidence persisting for variable periods, in some cases for years), that this immunity is probably acquired by previous attacks."

Daniels also observed that the spleen is frequently found to be enlarged, and very much enlarged, without showing any pigmentation at all, and inferred from this that there might be some other cause besides malaria for the enlargement.

In my study of kala-azar [1899] I came to the erroneous conclusion that it was nothing but severe chronic malaria. Arguing from Daniels's observations, I thought that the unpigmented enlargement of the spleen in this disease was due to numerous previous attacks of malaria followed by partial immunity and natural elimination of the pigment (plasmodin). Kala-azar is now known, of course, to be caused by another parasite; but I still think that the pigment may be eliminated in cases of malaria after the parasites have died out—thus explaining its absence from old malarial enlargements.

A little later, R. Koch observed that the parasites can usually be found more frequently in children than in adults, and suggested the examination of the blood for measuring malaria. His figures are given principally in his third Report [April 1900]. At Stephanore, out of 334 persons the parasites were found in 127, or 31.4%. In Kaiser-Wilhelm-Land, at Bogadjim, out of 297 children of under five years, the parasites were found in 13, or 4.4%; while none were found in 86 persons of over five years in age. At Bengu, out of 29 children under five years, the parasites were found in 12, or 63.2%; out of 17 children from five to ten years, in 4, or 23.5%; and out of 39 persons from ten to forty-five years, in none (note, large error of random sampling).

Almost at the same time, Christophers and Stephens published similar figures regarding studies in the Gold Coast [June 1900]. They state that in four places the parasite index found by them was 50, 75, 71 and 23% among "babies"; 37, 30,
MALARIA IN THE COMMUNITY [Sec.
75, 20% among children up to eight years; 25, 0, 30, 0% in children up to twelve years; while children over twelve years showed parasites very rarely. They give no actuals.
During the same year, Annett, Dutton and Elliott made a survey of the parasite index in ten places in Nigeria [1902].
The collected results were as follows:

<table>
<thead>
<tr>
<th>Ages</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>7-8</th>
<th>9-10</th>
<th>10+</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. examined</td>
<td>27</td>
<td>45</td>
<td>42</td>
<td>41</td>
<td>65</td>
<td>67</td>
<td>78</td>
<td>108</td>
<td>360</td>
</tr>
<tr>
<td>No. infected</td>
<td>10</td>
<td>29</td>
<td>31</td>
<td>47</td>
<td>34</td>
<td>49</td>
<td>35</td>
<td>72</td>
<td>105</td>
</tr>
<tr>
<td>Percentage</td>
<td>27</td>
<td>63</td>
<td>63</td>
<td>51</td>
<td>27</td>
<td>69</td>
<td>35</td>
<td>66</td>
<td>29.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ages</th>
<th>8-9</th>
<th>9-10</th>
<th>10+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. examined</td>
<td>16</td>
<td>14</td>
<td>4</td>
<td>34</td>
</tr>
<tr>
<td>No. infected</td>
<td>4</td>
<td>4</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>Percentage</td>
<td>25</td>
<td>29</td>
<td>41</td>
<td>72</td>
</tr>
</tbody>
</table>

The figures agree well with those of pigmented spleen rates given by Daniels. There is a curious drop at the 6-7 age. The authors' tables are well compiled; but the numbers for the separate localities are too small to furnish definite results.
Panse (1902) gives the following figures for Tonga, East Africa:

<table>
<thead>
<tr>
<th>Ages</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>4-5</th>
<th>6-7</th>
<th>Adults</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. examined</td>
<td>16</td>
<td>9</td>
<td>20</td>
<td>15</td>
<td>48</td>
<td>54</td>
<td>102</td>
</tr>
<tr>
<td>No. infected</td>
<td>6</td>
<td>6</td>
<td>17</td>
<td>15</td>
<td>34</td>
<td>32</td>
<td>125</td>
</tr>
<tr>
<td>Percentage</td>
<td>37</td>
<td>67</td>
<td>88</td>
<td>87</td>
<td>88</td>
<td>30%</td>
<td>62%</td>
</tr>
</tbody>
</table>

Craig gives for Camp Stotsenburg, Philippines [1909]:

<table>
<thead>
<tr>
<th>Ages</th>
<th>1-5</th>
<th>6-10</th>
<th>Adults</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. examined</td>
<td>16</td>
<td>30</td>
<td>42</td>
<td>102</td>
</tr>
<tr>
<td>No. infected</td>
<td>4</td>
<td>12</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>Percentage</td>
<td>72</td>
<td>37</td>
<td>42</td>
<td>47</td>
</tr>
</tbody>
</table>

Similar figures are furnished by various authors, but the number of children examined is generally too small to yield reliable results. Often only percentages, which are, of course, almost useless, are given.
The comparative frequency of enlarged spleen in children has been known for a long time—certainly in India; but much more exact work on the subject remains to be done.
Craig well remarks [1909] that there are certain "rules"
governing immunity." In heavily infected localities, where nearly all the natives are probably infected and re-infected in childhood, nearly all the survivors must be partially immune in adult age. On the other hand, where only a smaller proportion of the natives become infected in childhood, many of the remainder may be attacked for the first time at later ages. This must be especially the case where there are seasons, such as a sharp winter or a hot dry season, during which infection ceases. I notice, for instance, that the law of Daniels is not much insisted upon by Italian workers.

From these considerations an important deduction, exactly opposite to the common opinion, may be drawn. Where there is much malaria, so many of the native adults will be immune that few of them should show signs of infection; and, conversely, where the adults are frequently attacked, the amount of malaria should be comparatively slight. In other words, if the malaria index amongst adults (parasites, fever, splenomegaly) is high, the malaria rate of the locality is probably low; and where the adult index is low, the rate is probably either high or low. If, therefore, a considerable number of adults are coming to hospital with fever or enlarged spleen, we should believe, not that the malaria rate of the population is usually high, but that it is usually low—comparatively, of course. If malarial immunity were complete, and if everyone were infected in childhood, no one would be ill afterwards. For example, if many soldiers in a regiment are attacked, we may infer that they have not been recruited from very malarious districts.

Unfortunately, however, we are not sure (a) how far immunity derived from a single infection protects against subsequent infections; and (b) how far immunity against one species of parasite protects against other species. Thus many partially-immune adults may suffer from short attacks of fever due to re-infection, especially by parasites of a species different from the one to which they have become habituated.

Practically, therefore, for the purpose of the measurement of
malaria, it is best to consider only the malaria index among children. Among adults the malaria index cannot yield very definite results; if high, it indicates that the malaria rate is comparatively low; if low, that the malaria rate is either very high or very low.

The study of large numbers of children is required to establish the age at which the malaria index is highest. Most of the figures suggest that that age is between one and three years. Similar studies are required to determine the age of maximum average spleen, and of maximum enlarged spleen.

Determination of the inoculation rate.—According to section 26, the malaria rate of a locality is the percentage of the people who, at the moment of enquiry, contain plasmodia. But as many of these people must have been inoculated weeks, months or years previously, the malaria rate does not directly inform us as to what is going on at that moment—it instructs us regarding the past rather than the present. We may wish to know how many people are actually being inoculated during the week, month or year of observation; and if we can ascertain this we can obtain a measure of the actual malariousness of the locality at the moment when we are investigating the malaria in it.

This could be ascertained experimentally if we could distribute throughout the population a large number of healthy, non-immune immigrants, and could then observe accurately how many of them become infected within a given period; or if we could observe a large number of non-immune immigrants, and learn how long, on the average, they remain healthy. Such studies can sometimes be made with adults; but, unfortunately, Nature herself is always carrying out the experiment for us by providing a constant influx of non-immune babies, and we have only to ascertain the proportion of them which have become infected within a week, month or year after birth.

In his original article [1895], Daniels stated that in 44 infants who had died under one month after birth pigmentation
of the spleen could not be found; that it occurred in 12\% of 16 infants of one to six months of age, in 11\% of 14 infants of six to twelve months, and in 50\% of 11 infants of one to two years of age. From these figures we gather that in British Guiana at that time the chances were small that infection should occur within one month, and increased by about 3\% roughly for every month after birth—so that the chances were that about 50\% of all newcomers would become infected in two years. Meanwhile, however, immunity would tend to reduce the cases. Of course, with such small actuals, the error of random sampling is very large.

R. Koch in his third Report [1900] states that in nine localities in Java, the parasites were found in 67, or \( \frac{2}{3} \), out of 619 infants of under one year examined; and in 47, or \( \frac{3}{5} \), out of 574 children of over one year of age.

The *infantile malaria index* can easily be obtained by the parasite test or spleen test, or both combined, and, with large actuals, will give a good direct measure of the inoculation rate. But it will be still more useful if compared with rates calculated according to sections 27 and 28.

As before, let \( p \) be the total population, and \( m_1 \) and \( m_2 \) the proportion of infected persons at the beginning and the end of the enquiry respectively. Then at the beginning of the enquiry there were \( mp \) infected persons and \( 1 - mp \) healthy ones. Now let \( r \) be the number of infected persons who recover during the enquiry—suppose that \( r = 1/5 \) and that the enquiry lasts one month; and let \( \lambda (1 - mp) \) be the number of healthy persons who become infected during the enquiry. Then by section 28, equation 4,

\[
m_2 = m_1 p + (1 - m_1 p) - rp
\]

or

\[
\frac{m_2 - m_1}{m_1} = p - \frac{mp + rp}{m_1}
\]

Thus suppose that, in a village of 1,000 people, there were 250 infected persons at the beginning of the month and 300 infected persons at the end of it. Then, obviously, though 50 infected persons recovered during the month, there was
nevertheless an increase of 50 infected persons at the end of
it; so that 100 healthy persons must have become infected
during the month. That is, $\frac{1}{1-m} = 100$.

Here $J = (1 - m + rm)(1 - m)$, and is the inoculation rate;
that is, it gives the proportion of people, healthy or unhealthy,
inoculated during the enquiry. In the above example $J = 100$,
and of the 250 originally healthy people in the
village 100 were newly infected, and out of the 250 previously
infected people 33 were reinjected (i.e., gives the number of
reinfections); so that altogether 133 persons out of 1,000 were
inoculated during the month. The inoculation rate of the
village was $J = \frac{133}{100}$; that is, the chances of a new-
comer in the village, or of a new-born child, becoming infected
during the month was 133 to 100.

From equation 1 of section 27, we might infer roughly that
there were about 106 Anopheles to each person in this village.
In fact, on comparing that and the following section, we see
that $J = 1.6$.

The fractions $x, m, f$ and $r$ are connected by the equation
$x = m + f(1 - m) - rm$, and if we can ascertain any three of
them we can calculate the fourth—which enables us to com-
pare observed and calculated estimates. If the malaria is
static, so that $x = m$, then $f(1 - m) = rm$. We may now esti-
mate $J$ from the infantile malaria index, $m$ from the general
malaria index, and $r$ from statistics, and check our results by
comparison. Suppose, for example, that $r = 1/5$ a month, and
that 4% of the infants are infected in a month; then the
general infection rate of the locality should be about 16.6%.
Comparing these figures with observed estimates, we shall
probably arrive nearer to the truth than if we had relied on
calculation or observation only.

Practical conclusions.—Having considered the various
methods of measurement which may theoretically be adopted,
it remains for us to select the best ones for practical use.

A. First suppose that we wish to form an Actual Estimate
of the *Malaria Rate*; that is, of the percentage of people who contain plasmodia at the moment of observation. We may employ (a) the parasite index, (b) the spleen index, and (c) the combined methods.

(a) The **parasite index** gives exact information only as to the lowest proportion of infected persons. The proportion of those who contain plasmodia in numbers too few to be found during the time allotted for the test may be very considerable, and has not been correctly estimated. The test requires a skilled observer, and the expenditure of so much time that it can be applied only to comparatively few people. The error of random sampling is therefore generally very large.

(b) The **spleen index** (by palpation only) can be quickly ascertained, by almost any intelligent person, for large numbers of people—so that the error of random sampling may often be reduced nearly or really to zero. A certain proportion of infected persons have no palpable enlargement of the spleen, and possibly in others with palpable enlargement (especially with great enlargement) the parasites may have died out in consequence of immunity; but by the penultimate paragraph of (2), these two sources of error (amounting to say 20% each) will tend to annul each other, so that the spleen index should be a nearly correct measure of the true malaria rate. Quinine, local conditions and other diseases (especially kala-azar) may affect the spleen index, but in most countries probably only to a small extent. Percussion of those who show no palpable enlargement will reveal a greater proportion of cases; but with this test the infected non-spleen ratio will not be balanced by the non-infected spleen ratio—so that percussion may give a ratio further
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from the truth than that given by palpation alone. Percussion will also demand more time and skill.

(c) The combined methods (on the same persons) will yield a greater malaria index than each method by itself—often a much greater one than that given by the parasite index by itself, and a considerably greater one than that given by the spleen index. If, however, Laveran, Thayer, Mannaberg and others are right in their opinion that some enlargement of the spleen can be detected by percussion in almost all infected persons, then the combined parasite index and spleen index (by palpation alone) can yield little more information than that given by a careful spleen rate ascertained by percussion. The combined method will, however, require much more time, and will give no exact information regarding the non-infected spleen ratio.

Subject to correction, then, I conclude that, as a general rule, the spleen index (obtained by palpation only) is by far the best method of measurement. It requires no great skill; it can often be applied to almost all the people in a place; and it should yield by itself a very correct measure of the actual malaria rate. As a rule, local conditions, race and other diseases are likely to cause a percentage of error far smaller than that due to the insufficient random sampling which must almost always attend the labious estimation of the parasite index (the advocates of which frequently overlook this important point). But of course, in the presence of other widespread causes of splenomegaly (kala-azar or some unknown cause), the spleen index by itself will not be so reliable.

Practically, therefore, it comes to this, that we must avoid two principal sources of error, (a) the possibility that the local splenomegaly may be due to other causes than malaria, and (b) the great error of insufficient random sampling. For the former purpose we must first satisfy ourselves, by the study
of hospital records, especially of autopsies, by consultation with local physicians, and by the blood examination of selected cases, that the local splenomegaly is really due to malaria. For the second purpose, if the first point is established, we should rely upon a large spleen census. The time required for a laborious study of the parasite index will generally be much better spent in extending the spleen census so as to avoid large error of sampling; and the combined method will only occasionally be required for some special purpose, such as ascertaining the infected non-spleen ratio, or the infantile malaria index.

We must, of course, always consider the season, the time allotted for the work, the amount of assistance available, and the population and area to be examined. For large populations, the parasite index becomes almost impossible. Not the least advantage of the spleen index is that it can be applied equally well to a population of any size.

B. The actual infantile malaria rate. This is especially valuable by (10) for determining the inoculation rate. It can often be obtained among infants on estates and factories, in soldiers' families, and in many villages. As, however, infants up to one or two years of age are not always very numerous among small populations, and the information required is important, it is generally advisable and possible to use combined methods for examining them. The ages should be obtained as accurately as possible for each month for two years, and the infants examined as regards spleen, parasites, fever, anaemia and history of illness.

The information obtained should be compared with the formula at the end of (10). If we assume, as argued above, that the general spleen index practically coincides with the general malaria rate, and denote the spleen ratio by \( S \) and the infantile ratio by \( I \), then the formula becomes

\[ S = S + I (1 - S) - rS \]
If \( S_1 = S, \ r = 1/5 \) a month, and \( I \) is a monthly infantile rate, then we should have \( I = S/5(1 - S) \).

It is, of course, best to examine, if possible, all the infants and to compare their numbers at different ages with the numbers given by, or calculated from, the last census of the population.

C. Comparative estimates from time to time or place to place—For these we adopt the same methods according to the same principles. But we can now often utilise the valuable information given by the attendances at hospitals and dispensaries (5). That is, we obtain the ratio of attendances for malaria to attendances for all causes, and compare them from time to time or place to place.

Remember that, for comparative estimates, ratios of indices should, ceteris paribus, be equivalent to ratios of actual rates—which makes the task much easier.

The conduct of the malaria census will be referred to in connection with the whole campaign (section 40).

32. The Mortality and Cost of Malaria.—A little consideration will convince the reader of the difficulty of this part of the subject. The term "malaria death-rate" should mean the percentage of persons who die of malaria. Such rates can easily be obtained in the case of plague, cholera and other diseases in which the cause of death can be generally assigned with certainty; but malaria is a benign and protracted disease which is often complicated and terminated by other maladies, such as pneumonia, infantile diarrhoea, dysentery, ascariasis, and so on; and it is often, perhaps usually, impossible to say whether death has not been due as much to one of these complications as to the original infection. Even with troops and prisoners the cause of death in such cases is often assigned to one or the other cause on the evidence of the most predominant symptoms at the end. Even if we admit the correctness of the diagnosis as regards
deaths in hospital, still the hospital case mortality is no correct

guide to the total case mortality, because only the more acute
cases among the general population come to hospital at all.

Probably the great majority of malaria deaths occur among

the children of the poor, and in the tropics these are seldom

brought to hospital, or even attended by medical men. The

fact that in most tropical countries the cause of death is not

necessarily certified by medical men adds still more to our
difficulties. Indeed the so-called malaria death-rates given in

many statistics are not even worth looking at.

The parasites of malaria cause death in two ways: (a) by
direct action, and (b) by enfeebling the constitution.

Deaths by direct action probably occur only in “pernicious
attacks.” Celli (section 30 (6)) records that 330 pernicious
attacks occurred in 33,507 cases—about 1%, and of these
probably only a fraction were fatal.

W. H. Deaderick collects many useful facts in his text­

book [1909] and gives records of case mortality amongst them.
Out of 5,159,001 cases collected from twenty-five writers,
145,015 or 2.89% died (I judge that these were mostly severe
cases treated in hospital). Out of 27,039 cases of

pernicious malaria, recorded by thirty observers, 7,205, or 26.6% died.
Out of 6,037 cases of blackwater fever (one of the most

pernicious forms), 1,268, or 21% died.

In India for 1907 we have the following figures (combining
intermittent and remittent fevers):—

<table>
<thead>
<tr>
<th>Strength</th>
<th>Admissions</th>
<th>Deaths</th>
<th>Malarial mortality</th>
<th>Case mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>European troops</td>
<td>86,555</td>
<td>10,666</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Native troops</td>
<td>199,515</td>
<td>28,432</td>
<td>84</td>
<td>65</td>
</tr>
<tr>
<td>Prisoners</td>
<td>93,164</td>
<td>17,541</td>
<td>22</td>
<td>18</td>
</tr>
</tbody>
</table>

The highest malarial mortality here given, that of the

prisoners, may be put at about 1/1000; but we can see at

once that this is sure to be too low an estimate for a large
general population. Troops and prisoners live in cleanly sur­

roundings, are well housed, well fed, well treated in hospital,
and (still more important) are all adults. Moreover, in my experience, medical men rarely attribute death to malaria alone unless there are no very marked complications. The rate amongst a large, poor, general population, including children, is therefore likely to be several times greater. But we have no figures to indicate the difference.

As just mentioned, the deaths attributed in public statistics to malaria are generally worthless in the tropics, as they are not even certified to by medical men. They are often much too high, because the perplexed registrar has no other cause to give when dysentery, cholera, fits or debility fail him. For example, in Mauritius the deaths attributed to malaria constituted 14 per mille, or about half of the total mortality. In 1899, however, the medical certification of deaths was enforced in two districts of the island—with the result that the mortality ascribed to malaria fell in them at once from 40% of the total deaths to only 25%. From this we calculate that quite 20% of the general mortality was wrongly ascribed to malaria. But even with this correction many sources of error remain.

Is there no better criterion of the true malarial death-rate? In most civilised countries to-day the total death-rate is correctly reported: we may therefore obtain useful information by comparing the total mortality in various areas which differ in possessing or not possessing malaria, but which are alike in other respects. Take, for example, Mauritius (malarious) and the neighbouring Seychelles Islands (not malarious).

For the seven years 1897 to 1903 the mean death-rate in the Seychelles was only 17.1 per mille against 34.7 in Mauritius. If the whole of this great difference is to be ascribed to malaria
alone, we must suppose that the true malarial death-rate in Mauritius may average something like 20 per mille per annum or more—that is, a mortality exceeding the total mortality from all causes in the Seychelles and in most British towns.

The figures are accurate, the deaths being carefully registered both in the Seychelles and in Mauritius, and the islands have a very similar climate. But in the mountainous Seychelles there are few or no Anophelines as in Mauritius. The population of the former, however, is of negro origin, and in the latter of Indian origin and much more dense.

The following are some figures for ten other neighboring islands of the Indian Ocean—all not malarious. The populations were those of the census taken in 1901, and the death-rates were the averages for the following five years. Rodrigues, 5,437, 19.3; Diego Garcia, 526, 27.0; Açalogas, 327, 31.2; Pêna Franque, 134, 24.7; Cotta, 143, 27.4; Solamen, 116, 32.0; Sir Islands, 177, 29.0; St Brandon, 57, 11.2; St Jean de Noise, 74, 16.0; Eagle Island, 74, 4.0. Total population, 5,134. Average death-rate, 21.3. Owing to the smallness of the population in the lesser islands, the statistical error is large; but the mortality in some of them, in spite of the absence of malaria, appears to be as great as that of Mauritius. There is, however, an important difference. In Mauritius, the Seychelles and Rodrigues good medical attendance is available, but this, I understand, is not the case in the other islands, where syphilis, beri-beri, infantile tetanus, bowel complaints, ovarian and uterine diseases abound, and deaths in child-birth are common. Excluding these islands, therefore, the difference as regards the mortality between Mauritius with malaria, and Rodrigues and the Seychelles without it, remains a striking one. The large malarious island of Réunion (negroid population) has a mortality similar to that of Mauritius.

The entry of malaria into Mauritius in 1866 is interesting in this connection (section 30 (21)). All deaths in the island have been registered since 1831. In the thirty-six years from
1831 to 1866, the average death-rate was 35.3 per mille in a population varying from 95,000 in 1831 to 365,000 in 1866. In the next five years the death-rates were 120.5, 56.7, 35.0, 22.6 and 44.1 respectively; and in the forty years from 1867 to 1906 they averaged 35.7—almost the same as before the entry of malaria. Thus, apparently, while the disease caused a great increase of mortality for two years after its entry, it has caused no increase whatever since then! In my report [1905] however, I have discussed this anomaly. As Dr. Meldrum suggested, the extraordinary low mortality of 1870 was possibly due to the death from malaria of many persons in 1867 and 1868 who would otherwise have died in 1870. The high death-rate before the entry of malaria was probably due to many epidemics of measles, small-pox, relapsing fever and cholera, and to the immaturity of medical and sanitary practice in those days. Since the entry of malaria there have been few of such epidemics, and medical and sanitary practice have greatly improved, while vaccination has been rendered compulsory—so that the death-rate should have fallen to the low level found in Rodrigues and the Seychelles. Hence we may perhaps assume that it has not fallen because of malaria. In other words, the disease has counterbalanced all the successes of medical science against other maladies.

The late Dr. Meldrum, Director of the Meteorological Observatory in Mauritius, and an experienced statistician, studying the monthly death-rates from all causes in Mauritius before and after the entry of malaria, observed that they differed in an important particular. Before the malaria entered they remained roughly the same from month to month; after it entered the curve rose markedly during the malarious months. In the Seychelles and Rodrigues the monthly rates still remain uniform as in Mauritius before malaria entered. The following table gives the population and number of deaths.
in the first two lines the monthly deaths are fairly uniform; in the latter two they are lowest in November or December, before the malaria season, and highest after that season. Meldrum also enunciated another law based on the careful study of Mauritian statistics, namely, that the highest death-rate generally occurs about two months after the heaviest rainfall. But the figures for other countries show that there may be many disturbing factors—heat, cold and epidemics. Nevertheless, Meldrum's laws should be used, together with other data, in the study of local malaria death-rates (1881, 1890). We should endeavour to ascertain the average ordinary mortality, exclusive of epidemics, during the non-malarious months, especially those just before the commencement of the increase probably due to malaria. The difference between this average and the total mortality during what we have reason to suppose are the months of malarial mortality should give some rough indication of the amount of the latter. S. R. Christophers has recently suggested (1910) that rises in the total mortality, minus other epidemics, should indicate epidemics of malaria. They should also indicate endemic variations. But of course in all such studies an accurate knowledge of local circumstances—climate, rainfall, other diseases—is required.

So far as I can see the only method by which we can hope
to ascertain the increase in the general mortality really due to malaria would be to undertake a careful comparison of the death-rates and spleen rates over a large area and for a considerable period. The task would be a suitable one for all Health Departments, and ought to have been performed long ago— if only to determine that fundamental question, the actual amount of mischief caused by the disease.

In 1898 I proposed to undertake such a survey in Mauritius, and collected a number of figures from the sugar estates (1898). Unfortunately, the death-rates could not be obtained for the period during which the spleen rates were taken; and other fallacies invalidated the data. In section 22, however, the rates are given for the various districts of the island. The healthiest district, Moka, showed a spleen rate of 4.4% and a death-rate of only 18.7 per mille, while Black River had a spleen rate of 16.7% and a death-rate of 39.5% (on the estates). This again suggests—as we saw from a comparison of Mauritius and the Seychelles—that malaria, when severe, may actually double the general mortality. But before accepting such an appalling estimate I should like to see the subject worked out step by step—I should like to know for several countries and races the rise in the mortality step by step for every rise of 10% in the spleen rate. Until this is done we remain merely in the clouds of medical conjecture.

What precisely is the economical loss to the community caused by malaria?—From the preventive point of view this is perhaps the most important question before us; because, obviously, it governs the question of the expenditure which may be demanded for the anti-malarial campaign. In order to answer it we must know (a) the real malarial mortality; (b) the constantly sick rate (section 31 (6)); and (c) the local values of human life and labour at various ages and in various social classes. Considering the importance of the theme, I had hoped to give here a detailed estimate; but I find that the data are quite insufficient. We do not know even the real death-rate,
much less the death-rates at various ages; and the values of
life and labour vary so much that different estimates must be
prepared for each country.

Many such estimates have been attempted. I will mention
here as an example only one by Dr Bolton, Medical Officer
of the Immigration Department of Mauritius (because I have
already given so many statistics of that colony). There are
about 39,000 adult male coolies on the sugar estates, of whom
about 15% are incapacitated by malaria for three months in
the year. That is, more than 70,000 days' work is lost
annually. The day's work is worth 3.4 rupees to coolies and
3.4 rupees to the planter; so that the coolies lose about 133,000
rupees and the planters about 62,000 rupees per annum, or
73,000 rupees altogether. Besides the males there are about
8,000 women working on the estates, and, at the same rate,
these lose 21,000 days' work, worth 21,000 rupees at 0.20
rupee a day. Similarly, outside the estates, there are about
30,000 Indian coolies, earning 0.5 rupees a day; and these lose
about 20,250 rupees a year. Thus the workers lose about 166,250
rupees per annum, and the employers considerably over 650,000
rupees. With hospital and other expenditure Dr Bolton
estimates that malaria costs Mauritius, with its population of
383,000, about 1,000,000 rupees a year (a rupee is about 1/15
pound English)—that is, about 26 rupees per head. Enhance-
ment of wages, cost of invaliding, and loss of market are not
considered. Similarly, L. O. Howard estimates that malaria
costs the United States $100,000,000 a year (section 41). See
also section 65 (9).
CHAPTER VI

PREVENTION

33. List of the Possible Preventive Measures.—One advantage of the malaria formula given in section 28, equation 4, is that it enables us not only to name the various preventive measures, but also to obtain some quantitative estimate of their relative utility. Suppose that an anti-malaria campaign is contemplated in any locality, and let \( m_0 \) be the proportion of infected persons at the beginning of the campaign, and \( m_1 \) be the proportion at the end of a given period. Then by the formula

\[
m_1 = m_0 + \frac{1}{5} \ln \left( \frac{1}{1 - m_1} \right)
\]

Hence \( m_1 \) will be less than \( m_0 \), that is, the malaria will be reduced, if we can make suitable modifications in the factors \( b, s, a, i, r \). Such modifications can be made in various ways, as follows:

The biting factor, \( b \), represents the average proportion of Anophelines which succeed in biting individuals. We have roughly estimated it at \( 1/4 \). Obviously, if we diminish this fraction we shall diminish the malaria in the locality. This can be done in many ways. The use of ordinary mosquito-nets, of mosquito-gauze to the windows and doors of houses, of punkas and fans (which drive away the insects), and even the use of smoke, woolen clothing and bed coverings, must all tend to have the desired effect. But, of course, if we hope to reduce the malaria throughout a considerable
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POSSIBLE MEASURES

The population, such measures must be adopted by a sufficiently large number of people. No appreciable effect will be produced on the general malaria rate if only a few persons take the trouble to use them, because \( \delta \) expresses the average proportion of insects which succeed in biting.

The next factor in the equation is \( \beta \), which denotes the proportion of insects that succeed in maturing the parasites, and which we have generally taken at about 0.3. This factor depends principally upon the species factor of the local anophelines (section 30). Certain species certainly succeed in maturing the parasites more easily than others do, and, moreover, it has been suggested that certain foods inhibit the growth of the organisms in the insects, while cold also does the same thing. I fear that we are unable to modify this factor by itself.

The next factor, \( \alpha \), denotes the number of different anophelines to each person, and can be modified by any of the measures adopted for mosquito reduction; that is, the adults may be killed by hand, or by various culicicides, or perhaps by the introduction of enemies, such as certain bats or birds. Or the larvae may be destroyed in numbers of ways, such as emptying out the water containing them or applying ovicides of various kinds, or introducing certain fish or other enemies. Or the breeding of the insects may be checked by removing water suitable for larvage or the weeds in which they often flourish. Or the locality may be rendered unsuitable for a given species of anopheline by doing anything to modify the conditions which that species loves, such as removal of rest or undergrowth. Lastly, reduction of the biting factor, \( b \), may tend to reduce the total mosquito density, according to section 29 (7).

The factor \( \iota \) denotes the average proportion of infected persons whose blood contains the sexual forms. This can be modified to a certain extent by the careful treatment of the patients—though we must remember that quinine does not
have much influence on the crescents when these are once produced (sections 23 and 65).

The factor \( r \) denotes the average proportion of infected persons who recover during a given period, and this can certainly be very largely modified by suitable treatment of the sick. It is true that certain authors declare that quinine does not have much effect on relapses (section 23), but in the opinion of a majority of observers early and continued medication certainly produces marked results. Such treatment of persons who have had declared symptoms of the disease should be called case reduction; but we should observe that a similar treatment may be commenced in persons before they have had any symptoms at all. That is to say, all persons in a locality may take quinine continuously on the chance that they may have happened to have become infected without their knowledge, and in the hope of checking the parasitic invasion at its very outset. This method of dealing with the disease should be called quinine prophylaxis. For case reduction we treat the sick, for quinine prophylaxis the healthy.

It will therefore be observed that we have many preventive measures against malaria, but the ones given do not close the list. Another important measure is that of segregation. Instead of destroying the local mosquitoes or their breeding-places we may segregate ourselves or a number of people from their haunts; and, obviously, this will have the same effect upon the segregated people. Or we may segregate ourselves or a number of people from the infected area by removal to any locality where the original malaria ratio \( w \) is less.

The reader will now do well to suppose various values for the factors in the equation and then to calculate that of \( n \) on these suppositions. Suppose, for instance, that the malaria ratio has been remaining at the static limit of one-half, so that by section 28, equation 4, the number of Anophelines, \( a \), should be about 77 to each person. Now suppose that \( a \) is reduced to one-half; then \( n \) falls from 1/2 to 9/20. Next, suppose that
is reduced to one-half: then \( w \) falls to 17/40—a slightly lower figure, because the factor \( b \) in the equation is squared. Lastly, suppose that \( r \) is increased by proper treatment to twice the previous recovery rate of 1/5: then \( n \) becomes 4/10—which is still lower. But if we increase the recovery rate we are likely also to decrease the proportion of persons with gametids in their blood, \( e \). Suppose that if the first is doubled the latter will be halved: then \( w \) falls from 1/2 to 7/20. Lastly, suppose that several of the factors are changed simultaneously—for example, reduce \( a \) and \( z \) to 1/2 and double \( r \); then \( n \) falls to 13/40. This subject will be discussed again in section 39, but the reader should familiarize himself at once with the ideas involved in order to understand the following matter.

Many of the measures were first named and discussed in my little book called "Instructions for the Prevention of Malaria Fever," and my series of articles in the British Medical Journal, both published anonymously in the autumn of 1899. The principles then laid down by me have since then been repeated in many papers and textbooks. We now proceed to examine them in detail.

34. Protection against the Bites of Mosquitos.—(1) Portable bed-nets.—The bed-net was well known to the ancients under the name of coropea (section 1). It is now used almost everywhere in the tropics by those who can afford it, and adds greatly to the comfort of life, apart from the prevention of malaria. Long before the connection between malaria and mosquitos became known, General Outram of Indian fame, and Emin Pasha of African fame, and others, attributed their immunity from the disease to their care in the use of the net. In fact, when I went to India in 1881, it was a common saying amongst sportsmen, planters and many residents in that country, that the way to keep off malaria was to use a net under all circumstances.

\[ \text{Or we can use the static formula, section 28, equation 7.} \]
PREVENTION

But the net must be used properly, and the following rules carefully attended to:

(i) Not a single rent or hole in the net must be allowed. If there is one, mosquitoes, which spend the whole night in exploring every inch of the net in the hope of reaching the sleeper, are sure to find it and enter. Not only should there be no rent or hole, but the net should be so hung that no aperture for entry is left. Thus it should always be hung inside the poles provided for the purpose, and tucked continuously all round the mattress. It should not be hung outside the poles, because then it cannot be tucked in satisfactorily in the manner mentioned; and it should not be allowed to hang down to the floor unless heavily weighted, because then it is apt to be blown up by the wind, thus allowing insects to enter. Moreover, if it is hung down to the floor, insects which are hiding under the bed during the daytime will often be included. The servant should be instructed to let down the net before dark in the evening, and to see that no mosquitoes are inside. If mosquitoes do find entry, it is always due merely to carelessness.

(ii) Do not have any opening for the purpose of entering the net. Such openings are often used in Europe and allow the insects to go to bed with the sleeper. When entering, one should lift the lower edge of the net from the mattress as little as possible and slip in with a twisting movement, so as to exclude stray mosquitoes which may have been hovering round outside. If possible, use a large bed and a large net in order to avoid the hands, knees and elbows being pushed against the gauze during sleep, and thus being bitten through the net by mosquitoes outside. If no large bed and net are available, this contingency
should be guarded against by sewing a loose valance of gauze round the lower part of the net, about 9 inches (23 cm) above the upper surface of the bed, the valance being tucked under the mattress top edge with the net.

e) The thread of the netting should not be too thick, as if it is so it will exclude air. The mesh should be neither too small nor too large, the general size fixed being about eighteen threads to the inch (seven to the cm.). No part of the net should be made of any closer texture; as this is quite unnecessary and excludes the air. For example, where, as in India, punkas swing over the bed all night, a top of calico merely excludes the breeze and adds to the discomfort of the sleeper. Of course, where sand-flies (Simuliidae) are present, the whole net must be made of closer texture, such as muslin or cambric. These insects inflict worse torture than mosquitoes do, and have also been proved to carry a particular kind of fever. The netting should always be white to permit the easy detection of insects.

f) In the great heat of the tropics, the manner in which the net is hung is very important. If it is arranged in thick or loose folds it will exclude the cooling breeze. The net should always be stretched as tight as possible in every direction, in order to allow the air to pass freely through it. In fact, those who complain that they cannot sleep under a net because it stifles them nearly always neglect this precaution. A tightly-stretched net with a thin thread excludes very little breeze. For this reason the pattern of net is important. In my opinion much the best nets are the square ones which are used almost throughout India, and which are capable of being stretched in the manner described. Nets which are bunched up
at the top and hung from a single rope are much more loose and uncomfortable for the sleeper; but there is a good pattern which contains a circular hoop a yard or two above the bed, permitting the necessary light stretching.

(e) Many patent patterns are advertised, and nearly all of them are good ones. Different patterns are required for fixed or Portable tents and for travelling. The traveller needs a portable pattern which can be set up very quickly in any locality where he may require to sleep. Bed-quiltS with attached nets are also on the market, and can generally be obtained locally. Special patterns have been suggested for soldiers and others who have to bivouac in the open air. I generally carry a small square netting which can be hung inside the berth on board ship, because shipowners are still barbarous enough not to exclude mosquitoes by wire-gauze at the ports (section 46).

(2). Portable mosquito-proof rooms.—These are simply large nets, generally square and capable of holding the entire bed, together with a small table and chair, and perhaps a rotary fan. Several special patterns are on the market. They are very useful for travellers. Entirely mosquito-proof tents have also been advertised, and should certainly be always used in warm climates. The one difficulty about such structures consists in the arrangements for entering; but in my opinion it is not advisable to provide a special door for doing so, as one can always creep in under the lower edge of the net.

(3). Wire-gauze mosquito-proof rooms.—These are found in several colonies, and consist of a wire-gauze chamber supported by wooden uprights fixed in the floor. The mode of entry is by means of a self-closing door. The wire-gauze is in one respect preferable to the cotton netting, as it allows more breeze to enter, but on the other hand mosquitoes which have entered cannot so easily detected against the darker thread of the
wire. Of course, such chambers are constructed within the ordinary rooms of a house, or in the veranda. I have long advocated the use of them, during very hot weather, either in the open or on the roof of the house.

(a) Mosquito-proofing of windows and doors—This has been long in use in the Southern States of America, and has been much advocated by French and Italian writers on malaria. The net may be of cotton, but this, of course, soon rot away, so that wire-gauze is always better. I am very strongly in favour of this method of protection, which I have seen in use in Lagos, Panama and elsewhere. It adds greatly to the comfort of life in the tropics. It excludes not only mosquitoes, but flies, mosquitos and other insects, birds and bats. It also excludes the glare of the sun during the day, and the damp exhalation rising after heavy tropical showers. At the same time it allows the breeze to enter almost unimpeded.

The mesh of the net should be the same as that used for bed-nets. The wire may be either of "tinned iron" or of copper or brass. Roughly speaking, the price of the former is about twopence a square foot and of the latter about threepence a square foot in British colonies. Some years ago a number of tests were carried out by the Crown Agents for the Colonies on behalf of the British Colonial Office, showing that tinned iron soon rot away in consequence of damp. But I once saw in Lagos a greenhouse covered in entirely with tinned iron wire-gauze which had remained quite sound for more than five years, even in that warm damp climate. The question how the gauze should best be applied to the windows has been much discussed, especially by Laveran [1907], who gives many diagrams and pictures. As a matter of fact, the question has generally to be decided according to the form of the windows already existing in a house. The problem is an easy one with sliding sashes. In such cases I advocate that the wire-gauze be permanently nailed, with nails.
of the same metal (in order to prevent galvanic rust), outside
the window; that is, if the shutters are hung inside. For
French windows, which open outwards on hinges, the problem
is much more difficult, because if the wire-gauze is fixed inside,
the windows cannot be opened. Many types are adopted in such
cases, but they are not always satisfactory. Moveable wire-
gauze frames which require trouble to put up are sure to be
neglected by servants. In my opinion it is best in such cases
to refit the window so that they can be made to open inwards,
and then to fix the wire-gauze outside, or vice versa. Further
details are better left to the intelligence of the reader. In
climates which are never cold, the glass of the windows can
be replaced entirely by wire-gauze, thus simplifying the problem.

Doors afford another problem. The Italians have long
adopted double sliding doors with a protected entry, but
this is necessary only where the insects abound very much.
Automatic sliding doors generally suffice. Of course, in order
to protect a room or a house completely, every possible orifice,
including key-holes, chimneys and clinks round doors and
windows should be properly closed or guarded; but the details
are so numerous that it is useless to give them in writing.

Wurtz (1867) states that a solution of commercial silicate
of potassium in its own volume of water, if painted several
times with a brush, without drying between the coats, upon a
piece of ordinary cotton netting stretched over a window-frame
or elsewhere, will make the netting much stronger and more
resistant to water or fire. The painting can be done in five
minutes. The solution dries in an hour. The mesh should
be large, as the interstices are partially filled by the solution.
In this manner cotton netting can be utilized for window and
house protection. The suggestion is a very good one and
might be developed further.

(5) Mosquito proofing of verandas.—This adds largely to the
expense of protecting houses, but is, of course, a very great
addition to comfort. A large part of the Meteorological
Observatory in Mauritius was proofed in this manner at the cost of several thousand rupees, and the measure is much adopted in Panama and elsewhere. A much less costly procedure is to protect a single corner of the veranda. This was insisted upon by Sir William MacGregor in Lagos, and is now adopted in that colony. Something of the kind should always be used, as people must have somewhere to sit in having the evening.

(5) Protection for the hands and feet.—In 1898 many water-divergents advocated protection of this nature. It was suggested that white armbands should go on the march with soldiers over their toes and thick woollen gloves—a rather difficult suggestion for the tropics. The Italians have dealt with this matter at considerable length, and Lavran quotes and figures the protection given to Japanese soldiers in Formosa and Manchuria. Special boots to protect the ankles have also been recommended.

Personally, I think that such means of protection are too uncomfortable for general use, and I much prefer a band for mentioned presently.

(6) Medicinal protections.—Many attempts have been made to find protective applications to the skin. Oil of lavender, of eucalyptus, petrolatum, ammonia, powdered sandalwood, and many patent fluids have been recommended to this purpose, but when I have recommended them to others, I have not always received favourable reports regarding them. Lavran (1902) mentions numerous statements on the subject regarding sulphur, petrolatum, a mixture of tar and oil, and quassia. Vaseline (1000 parts), naphthaline (10 parts), camphor (1 part) has been recommended; but he adds that his own experience was unfavourable with such substances. Ferni and Lumbau (1900) tested many substances without marked success. Celli (1901) states that the old custom of hanging bags containing garlic or camphor round the neck originated in their protective effect against mosquitoes.

We should observe that experiments on the point must
in exact to be convincing; that the effect of volatile substances is sure to be transient; and that the use, even of successful protectives, can only be exceptional, as when mosquitos are very numerous, because few people will ever be persuaded to smear themselves constantly with them, and because they would probably affect the skin after a time. Such protectives do not come at present within the domain of practical sanitation.

(8). Constant movement.—As a general rule (but not always), mosquitos bite only when their victim remains quiet. Hence I have formed the habit, when in danger of being bitten, of maintaining constant small movements of the hands, feet and head. I find this, together with the use of a hand fan, far more efficacious than the employment of hot gloves, thick clothing or inunctions.

(9). Fans and Punkas.—A palm leaf can be purchased almost anywhere in the tropics for a penny, and serves not only to drive away mosquitos, but also to keep the body cool. Fans rotated by electricity or small hot air engines are now frequently used in the tropics by those who can afford them. Punkas consist of a board or canvas stretched upon a wooden framework, hung by one edge from the roof, and swung backwards and forwards by means of a rope or pulley worked by hand labour or (in barracks and hospitals) by machines. The constant movement and the current of air prevent mosquitos biting even a sleeping person. Probably the alternating movement has a better effect for this purpose than the uniform movement of a rotatory fan. The punka should not consist merely of a pole with a fringe of cloth hung from it, because the yielding fringe gives no current of air.

(10). Some results.—Perhaps the first example of the utility of ordinary bed-nets was cited by myself [22nd July 1896]. In October 1898 a company of the "Boys' Brigade" of Calcutta went to live for one week in a house in Barrackpur Park, near
the River Hoog-Iy. The three officers and a friend slept in bed-nets, but thirteen boys did not. The officers and their friend remained well, but all the boys, together with a sister of one of them, were attacked a few days later. The first boy attacked died. Mosquitoes were very numerous. Three native servants (without nets) also suffered.

In 1905 also many experiments were made on the Italian railways by screening stations and houses of employees. The results were summed up as follows by Celli (1905). Out of 2,965 completely protected persons, 1%, became infected and 21.1% had relapses. Out of 5,165 incompletely protected persons 17% became infected and 26.5% had relapses. Out of 806 persons protected only during sleep 19.5% became infected. The local fever index was 20.56%, or even more.

Lucanus (1905) quotes an experiment among Japanese troops in Formosa, of whom, out of 56 unprotected men, there were 285 cases of malaria, and out of 115 protected men there were none; and also cites several similar small experiments in Ceylon, Algeria, Holland and Bengal. In nearly all of these cases, however, quinine as well as protective screening was used. The experiment of Samson and Low (1900) served a useful purpose at the time in advertising the mosquito theory, but there was no very strong scientific evidence that the subjects would have been infected during the experimental period, even without the protection.

Further experiments should be performed in order to ascertain the effect of mechanical protective measures alone.

35. Mosquito-reduction.—This can be effected (a) by direct destruction of mosquitoes or their larvae, and (b) by rendering houses or localities less suitable for them or for the breeding of them.

(a) Destruction of adults by hand.—Large numbers of mosquitoes can be destroyed in houses by a very simple device—a small hand-net. This is made for a shilling or two by
tying a piece of flexible cane or other wood or wire in the form of a loop, to which a bag of white netting about 18 inches deep (23 cm) is attached. The net must be white and not green, in order to enable us to see the captured insect through the mesh. Any one can easily wear his persecutors by means of it, and thus obtain reprieve for some time.

Sir William MacGregor employed a boy to kill mosquitoes in this manner in his house in Lagos in 1890. In fifty rooms a long-handled net may be required to catch the insects under the roof.

Colonel Gorgas and Mr. Le Prince advocate carriages 47 and 48 the employment of men for this purpose and give examples. I think that every household should possess such a net and should instruct his servants to use it regularly. The same thing should be done in hospitals, barracks, military camps, and jails.

Much more could be accomplished by this simple method than has yet been attempted. Boys become very expert at catching mosquitoes. The offer of rewards of a penny for fifty Anophelines may quite possibly lead to a large slaughter by village children. Probably, for unit of cost and trouble, more mosquitoes can be killed by hand than by fumigation.

Fumigation — This method has long been employed, especially in Italy and the United States. The discovery of the carriage of yellow fever by *Aedes aegypti* gave great stimulus to it for sanitary purposes. In yellow fever it is absolutely necessary that every *Aedes aegypti* which has bitten the patient should be killed for fear lest it may infect other persons; and this is rendered easier because the yellow fever patient remains infective only for three days, and because *S. calopus* is a domestic insect. But destruction of adults is not so useful for the prevention of malaria, because patients continue to be infective at irregular periods for a long time, and because the carriers are often wild insects (section 29 (a)).
which may remain only an hour or two in houses. Hence the
expensive and troublesome process of fumigation is not
much employed in malaria prophylaxis.
Celli and Cesarelli made experiments with many sub-
stances [Celli, race]. Thick tobacco smoke and chloroform
appear to be the best, and have been known for a long time.
Sulphur dioxide, hydrogen sulphide, coal gas, & carbonic acid, kill
in one to two minutes that, curiously enough, arsenic gas seems
to be quite innocuous. Flames of pyroxylin powder causes
apparent death in five minutes and actual death in eight hours.
Numerous agents for the destruction of insects in greenhouses
are on sale and are equally effective against mosquitoes.

Bosio [1890] describes very thoroughly, and with good
illustrations, the methods of fumigation practised against
yellow fever in America. His recommendations have already
been given (section 121).

In India fumigation is seldom used; and it would be
difficult to apply in the thatched mud huts or leaf dwellers
of the poor. But I think that destruction by hand could be
employed more than it is.

Mosquito-traps were also described in sections 12 and 60.
With cellars, privies, stables and dark rooms are natural
traps in which the insects often congregate in large numbers
and can easily be destroyed.

(3) Introduction of natural enemies.—Bats, birds, lizards,
dragon flies and other flies are known to catch mosquitoes;
but whether their presence makes any marked effect on the
number of the insects is another question, which, so far as
I know, has not been studied.

It has been known for a long time that small fish devour
the larvae; and indeed the larvae were used for feeding the
fry of British trout introduced into India, in my memory,
before 1890. Fish, however, vary greatly in their liking for
the larvae. Thus in Mauritius the small gold fish which abound
in ornamental waters eat them, but not voraciously. On the
other hand, I saw in India in 1890-1891 minnows which we
devour a dozen or more in a few seconds and would vis-
ually swell after the meal. The waters of Panama contain
minute fish, less than an inch long, which is equally fond
of them, and which thrives in quickly running streams.

The same is true of the common small fish at Ismailia. On
the other hand, large fish often disdain such small prey. I
saw in a ditch in Calcutta full of small fish and also absolutely
a ditch full of small fish and also absolutely

Boyce [1900] well describes the larvacidal properties
*Gambusia affinis*, popularly called "millions," a min-
fish probably allied to the one which abounds at Puna.

Mr. C. Kendrick Gibbons in 1905 attributed to it the immur-
lation of Panama from malaria. The people keep these fish in
water receptacles, of which Boyce examined sixty with

fishing larvae. The Imperial Department of Agriculture
Barbados has introduced millions into Jamaica, St Kitts,
Antigua. Further references to larvacidal fish will be fo-
in Chapter VIII.

Tadpoles, *Nemateleotris* (the waterr haneae), and the lar-
va of several insects eat mosquito larvae; and indeed the la-
are often cannibals.

This part of the subject is of great importance and
now receiving considerable attention. Obviously, the use
of the measure must depend largely upon the habits of
local malaria carriers—whether they breed mostly in per-
nent pools where fish and their other enemies also can live
whether they abound elsewhere, as in evanescent rain-w
pools. The question depends entirely upon the local c-
ditions and requires local study.

No cheaper and better anti-malaria measure than

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1. J. Graytor-White suggests the importation of "millions" into India (10

2. The importation was not in accordance with the wishes of isolated. This was

in evidence, and the fish are being introduced.)

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extermination of Anophelines by natural enemies could be conceived or desired were such a thing possible. It may be possible in some places; while for other places we may not be able to find the suitable enemy. Unfortunately, experience proves that animals and plants often succeed, even in large numbers, the introduction of their most deadly enemies; they succeed in finding some refuge or other, and a state of commensalism is finally arrived at. For example, Anophelines abound in the Panama Canal Zone in spite of the fish referred to. It is only the academical hygienist who believes that any measure which suggests itself is sure to be practically useful. It may often happen, too, that the expense of maintaining the “enemy” will be greater than that of removing the breeding water entirely. Nevertheless, we should seek what allies we can find.

It has often been observed that parts of India where M. rospi, which seem not to carry plasmodia, abound are comparatively free from malaria. Quite possibly it may tend to crowd out other species, thus reducing them below the malaria-bearing limit, although it does not exterminate them entirely. Experiments on this point are much required, and I have suggested them tentatively for Mauritius. The comparative freedom of large tracts where the conditions appear to be favourable must be due to some cause. If we can ascertain the factor we may be able to introduce it elsewhere. See sections 39 (10) and (11).

H. Marcus Fernando, in a suggestive paper just to hand [1902], points out that though Colombo, Ceylon, is surrounded by low-lying grass fields, subject to periodic inundations, it is practically immune from malaria. This he ascribes to swarms of minnows and other enemies of mosquitoes. He states also that very hot dry seasons are often followed by much malaria, simply because they tend to destroy the aquatic enemies of the larvae. These views accord exactly.

\[\text{section 54}\]
PREVENTION with those already expressed in section 30 (1), (6) and (10).

Small rice fields are often not malaria—see in Madras town.

4. Destruction of larvae. The methods employed depend on where the larvae are found.

For small receptacles of water, such as broken bottles and crockery, empty tin, flower pots, guards, old buckets and tubs, few baskets, fallen palm leaves, etc., emptying out suffices for the moment. But such articles ought to be collected in suitable dust-bins, and the law regarding the proper deposition of rubbish ought to be strictly enforced.

Oil Method. This method, long known, was first elaborated as a public health measure in my reports on Sierra Leone [1856]. It is employed wherever the previous methods are inapplicable, or where the water is required for use, or where more permanent measures cannot be adopted at the time—that is, for water butts, metal cisterns of drinking water, wells, garden cisterns, washing waters, cesspits and so on. The method has now become familiar to all. The oil is poured on the water, so that it quickly forms a thin film all over the surface. The larv and pupae are no longer able to keep the surface by surface-tension and quickly drown. Laveran thinks that the oil chokes the breathing tube [1907].

The oil may be poured on the water out of a tin or kettle, or by means of a special syringe. For small pools, I advocated that each man engaged on the work should be provided with a tin of oil, and a bunch of rag tied to the end of a stick. The rag is dipped in the oil, which is now "painted" on the surface of the pool—but such details are unimportant.

It is best to use the cheapest oils in the local market. Refined petroleum spreads rapidly and well, but evaporates quickly. Crude petroleum is cheaper and makes a much more lasting film. For Ismailia I recommended an equal mixture of the two. Celli [1901] said that 0.7 c.cm. was the minimum amount required per square metre of surface, but Perel...
POOLS AND HOLES

If Launon [1900] required 50 c.c.m. and others various amounts, experiments in Europe are of little use; and the amount required depends on the quality of the oil, the heat of the sun, the amount vegetation, flies, etc., and should be determined locally. Jan-Taylor and I found crude cresote to be very useful in New Orleans; it is more deadly, but also much more expensive to crude petroleum. For killing larva in drinking waters, rachman recommended me to use eucalyptus or juniper oil. For pools it is advisable, and indeed sometimes necessary, remove vegetation before applying the oil.

My brother, E. H. Ross, described an automatic oiler for pools at Port Said, and Gorgas and Le Prince mention others working in oil.

Celi and Coagrandi [Celi 1901] and others describe experiments with many substances. Aniline dyes are active sprayers. Gallol and Green Malachite kill to a certainty in solutions of 0.03 and 0.025 and 0.25 and a mixture called arsclone appears to be very effective. They diffuse themselves continuously in water, are not volatile, and do not poison cattle, or crops. Celi says that larvicide costs from 12 to 15 lire for destroying larvae in 10,000 cubic metres of water. is said to have little action on the pupae.

Oiling should also be used for the tins of water placed under feet of tables and meat-safes in order to exclude ants and other vermin. Small pools of water on the ground, especially those which run after heavy showers, or in rocks along the margin of wells, or in gutters, open drains, and stone water-channels, are often quickly brushed out, water, larvae, and all, by means of a broom.

Holes in rocks and trees are best dealt with simply by lining up with earth or gravel as a temporary measure, or with concrete as a permanent one.

Plants which breed mosquitoes should be removed if possible. Mauritius, Eulheria splendida, a wild pine-apple with a
gorgeous flower, was planted in most of the gardens and kept the houses supplied with innumerable *Sempervivum monteagutii* Slane, until the wiser inhabitants rooted them up during and after my visit. Cut bamboo stems should be cut again flush with the next knot, or with the ground. Unfortunately, mosquitos often breed in palm trees and sugar cane — in which case I can recommend nothing but grease being applied at the off-shoot of the leaves. The household has often to determine whether he will sacrifice his plants to his comfort. It is mostly the *Culicidae* which breed in such situations.

Rain-water gutters along the eaves of houses are best dealt with by boring a small hole in the most dependent part of the gutter where the water stagnates. Heavy old metal cisterns, etc., not worth removal, can often be treated in the same manner.

(5). The purging of breeding waters — We now proceed to consider methods for rendering localities or houses less suitable for mosquitos or for their breeding. We will deal first with what I call "minor works."

Mosquitos, more especially the *Culicidae*, breed very much in collections of water, such as water-buts, cisterns, wells, cess-pits, etc., which cannot be dispensed with, and which should be so protected that the insects cannot lay their eggs in them. At the same time it is often necessary to ventilate the water. For this purpose we should apply covers which are so scrupulously well fitted that no insect can enter, and at the same time protect the ventilating orifice by wire-gauze. In many countries tubs are used outside houses to collect rain-water from the roof. A wooden top should be closely fitted and a hole of about 6 inches or more in diameter should be cut in it. Nail down a piece of wire-gauze on the outside of the orifice. The pipe which brings the water from the roof discharges over the orifice, so that the water flows directly into the barrel, being drawn out by a tap below. Similar devices can be employed for cisterns, but if these are made of metal and have badly fitting covers, considerable
difficulty is often experienced in making the proper arrangements, which must be left to the reader.

The subject of wells is of great importance in the tropics, as they are often the only source of drinking water. For the usual hygienic reasons the people should never be allowed to lower buckets and ropes into wells, as this frequently leads to serious defilement of the water. In my opinion every well should be furnished with a closely fitting cover, the water being drawn by means of a pump of some kind. But in order to ventilate the water, a hole protected by strong wire-gauze should be cut in the cover. I have seen excellent wells of this kind in several localities, notably at Bathurst, Gambia.

Cess-pits are frequently used, especially in French possessions, and are ventilated by long pipes which discharge at the roofs of the houses. We observed at Ismailia that Culicifer were breeding in large numbers in these pits, though they were entirely closed except for the ventilating shafts, down which adults found entrance and exit. To prevent this it is necessary only to protect the ventilation with strong wire-gauze. In badly-made cess-pits there are other orifices by which the insects can enter. These should be done away with as much as possible. If they cannot be completely filled up, the pits must be regularly oiled by some method (section 53).

96. Dealing with breeding-holes.—I have already mentioned that holes in trees and rocks should be filled with concrete, that is, with a mixture of Portland cement and sand or gravel. The best mixture for the locality should be determined by local engineers. Two men must work together, one carrying concrete and the other laying it into the holes. Mosquito breeding-holes in trees are sometimes very difficult to find, men or boys having to climb the trees for the purpose. Hence, when they are found their position should be marked on the tree by a conspicuous patch of paint for future identification. Inexperienced persons are apt to think that such work is altogether too much for human weakness to accomplish, but
as a couple of men can generally fill fifty holes a day, it is not long before most of the breeding-places round houses are disposed of. In many cases, moreover, the water in such holes can easily be liberated by cutting. If concrete is not available, earth, gravel, or stones often suffice perfectly for a considerable period. A little trouble guided by common sense is all that is required.

Garden cisterns often occasion much difficulty. Water is required for irrigating plants, and is often allowed to stagnate for weeks in the sisterns. The best way to deal with them is to direct that not too many of these cisterns be allowed to remain, so that those which are permitted to do so shall be in constant use. The frequent agitation of the water by the gardener generally suffices to check mosquito-breeding in it. The gardener should be instructed to deal with his irrigation water in such a manner as not to cause breeding of mosquitoes. Here, again, details can be better left to the reader.

Irrigation pits are often employed for cultivation, and are found to contain Anophelines, which live especially in the presence of grass and vegetation occurring at the edge of the water. These are often difficult to deal with, as the people occasionally require the water. If possible, they should be filled in, but if this is not possible, we can often render them unsuitable for larvae by dragging out the weeds and "backing up" the margins of the pits by filling with large stones, the stones being instructed to prevent the new growth of vegetation. A gang of men will deal in this manner with a number of such pits in a day.

Sewer pits, that is, pits from which earth has been taken for building purposes, are found everywhere, and are not always easy to deal with. They may often be filled up with ordinary town rubbish, but this should be ultimately packed into them closely and covered with a layer of earth. In some places they can be filled up at greater expense with stones brought from a distance, if such are available. Where
they cannot be filled up, the best plan to deal with them is by the method just suggested for irrigation pits. Where no stones can be obtained, and where the water cannot be drained away, our only resource is to depress the bed. Make the banks "steep" all round, and clear away all the vegetation, leaving the water as before. Such places are particularly suitable for the introduction of natural enemies of larve; but they must be examined from time to time to see whether they are really free from mosquitoes.

A number of small questions of this nature are apt to rise in connection with cultivation, and must be left to the ingenuity of the director of the works. Railway companies often cause much trouble by their borrow pits along the course of railways, and they continue to do so in spite of the protests of medical men. This is a point which should always be taken note of by the Government of the colony, who should insist upon the borrow pits being so made as to allow the water to run off. I know that in absolutely flat country this is difficult, if not impossible; but in such cases much can be done by making regular pits without marshy borders, and by insisting that these shall be kept free of vegetation, and shall be stocked with fish, etc.

Pit conduits and drains.—By this I mean water-masses and drains which run through masonry. In the course of time the masonry is apt to wear away, thus leaving breeding-holes. These holes can be dealt with by rebuilding, or by filling with concrete.

17. Training the banks of streams, rivers and lakes.—The word "training" is one used by engineers to signify making banks more regular or solid. Untrained streams and lakes are apt to spread over the ground beyond their margins, and to cause innumerable small breeding-pits, and the object of the training is to check this tendency. The director of the work must be guided by circumstances how this can best be done. In many places the water may be deepened, the earth
taken from the bottom being used to build up a steep bank. In other places large stones may be arranged along the margin. Everywhere the streams should be so dealt with as to allow the water to run freely, and above all, weeds should be dragged out of the water, while the banks are rendered as "clean" and permanent as possible. The Forest Department in Mauritius "civilised" a stream in this way, at the cost of only 0.57 rupees a running foot for both banks. While the much trading is in progress, holes in neighboring banks may be filled in with cement. Cattle often cause much trouble by leaving holes in muddy banks in which Anopheles breed with readiness. This problem is attacked in Panama by a rule that cattle be allowed to water only at fixed spots which are properly prepared by cobble-stones to prevent such breeding.

Exactly similar measures are required for rivers and lakes, but the works involved for them must often be taken under the heading of major works. Irrigation canals and irrigation works in general must be attended to on the same principles.

It is often stated that irrigation is not compatible with mosquito reduction. This is quite untrue, because in Ibmahia at the present day we have an example of the opposite. Ibmahia, though built in the desert, is now a well-watered garden without mosquitoes. Nothing but attention to the small details which I have mentioned is required, and the expense of the work is very small. Idleness always leads to excuse.

Small marshes can frequently be dealt with quite easily by these simple means, that is, merely by clearing the natural line of drainage. One mosquito swamp in Ibmahia, consisting merely of Indian workmen, made short work of considerable areas of marsh in this manner. Only common sense is required; but, of course, in other instances major works by drainage have to be performed in order to give a final outlet to the water.

Temporary marshes (section 30 (1)), can be attacked on the same principles.

* See pp. 166 and 450.
(8). Major works.—I divide all works for the reduction of mosquitoes into two classes, namely (a) such as we have hitherto dealt with, which can be performed by any intelligent person, and should be called minor works; and (b) those which require the advice of an engineer, and which should be called major works. Naturally, major works generally require a greater expenditure of capital than minor works, though this does not imply that they are always more expensive in the long run. As a general rule, I think, major works need not be undertaken until minor works have failed, unless expert advice to the contrary is given.

Marshes are of two kinds, those in which the natural outlets for the water are sufficient but have become choked by vegetation, cultivation, or other small obstructions, which can usually be removed by minor works, and those in which the natural outlets are insufficient and require deepening. For adequate dealing with the latter, levels must be taken and extensive works directed by an engineer, are generally demanded.

Marshes may be caused not only by insufficient outlets, but by excessive inlet. The water in a marsh may not come merely from rainfall over the marshy area, but from streams or drainage from beyond. Thus marshes are very apt to occur at the base of hills, small or large, the rainfall upon which runs out and stagnates on the plain. We must therefore consider whether we should increase the outlet or decrease the inlet; whether we should cut channels across a marsh in order to free the water in it, or carry intercepting trenches round it in order to remove the incoming waters.

In many cases, especially in marshes due to periodical inundations by streams and lakes, the problem of how best to deal with them can be solved only by an expert. The marsh may be (a) drained away, (b) filled up, or (c) converted into an open lake too deep to breed mosquitoes. Estimates must be prepared, and the engineers have to select the best plan.
The form of drain to be employed often requires careful thought. Drains may be (a) open channels cut in the soil; (b) open channels flushed with stone or concrete; (c) channels filled with large stones at bottom and graced above usable drains; or (d) various kinds of subsoil piping.

All major works require to be constantly kept in repair by minor works, that is, after the major work is done, there must be a constant expenditure for what engineers call "maintenance."

Though it may be quite possible to treat a given breeding surface by minor works only, yet the expense of this may be so great that it will exceed the interest on the money laid out for clearing the area by a major work plus the expense of maintenance.

In all these matters the advice of the local engineers should be sought. But this does not mean that the advice of the director of the anti-malarial campaign should be disregarded. They must work together. For instance, M. Watson notes (section 57), that open channels are quite effective in the lowlands of his district, because the local carrier will not breed in them; but piped drains are required in the uplands where the carriers breed in any open water-course.

Obviously the habits of the local carriers should always be ascertained and considered, because this is likely to diminish largely the cost of their reduction.

Engineering works made in ignorance or in defiance of this knowledge may do more harm than good. For example, I think that most of the malaria in Freetown, Sierra Leone, was due to the badly-made drains; and I have seen much malaria caused by other works constructed without regard to their possible evil sanitary consequences.

A whole book could be written on drainage of the soil as a...
prevention of malaria—the history of the subject alone would fill many pages. The reader will find further details in the next chapter.

10. Trees. Vegetation has long been known to affect malaria. In some places it seems to have a bad effect, and in others a good effect. Probably this depends largely upon the habits of the local carrier. We quite understand that certain mosquitoes prefer wooded country, while others like the open. Thus M. Watson finds that in his district one of the most important measures consists simply in clearing the jungle to a considerable distance round habitations. On the other hand, it has been sometimes claimed that trees round habitations exclude mosquito breeding in marshes beyond.

Suggestions were made some time ago that eucalyptus trees would have the effect of drying up the soil and that their odor is injurious to mosquitoes. Consequently many plantations of eucalyptus were made in Italy, Mauritius, India and elsewhere, but the results have been quite indefinite, as might be supposed. I certainly think that eucalyptus tends to dry up the soil, but whether it does so sufficiently to check mosquito breeding is another matter. The cost of making plantations will generally exceed that of minor works.

It is well known that trees exclude a great amount of damp, which is always favourable to mosquitoes and unfavorable to men. Grotto-induce, then, I am strongly of opinion that many trees should not be allowed in the proximity of houses or in the middle of towns in the tropics. In addition to giving wet moisture they exclude the breeze and increase the heat, because the amount of shade thrown by them scarcely compensates for the cooling effect of wind. In the case of houses surrounded by considerable grounds, trees are pleasant and beneficial at a distance from the house. As already mentioned, moreover, trees are almost sure to breed Culicidae in holes in their trunks and principal branches. I therefore think that every tropical country should possess strict rules empowering the health
department to control the growth of trees within, say, 100
metres of houses. In Port Louis, Mauritius, the Mayor, Dr
Laurent, very wisely made a great reduction in the forestation.
In the same place much discussion has occurred regarding
what are called the "river reserves." By an old law the forest
department insists upon maintaining a belt of trees in the
neighbourhood of each of the streams for the purpose, partly
of preserving the streams, and partly of maintaining the rainfall.
forests being found to increase the number of rainy days, a
thing which is very useful for various kinds of cultivation. On
consideration I was very doubtful as to the effect of such river
reserves, but suggested that in the neighbourhood of towns
and villages they should be kept scrupulously free from
undergrowth.
As a general rule undergrowth is favourable to subdomestic
and wild species of Anophelines, which, after leaving houses
where they find their food, like to take refuge in thick vegeta-
tion. Personally, I prefer houses surrounded by open lawns
rather than by thick shrubberies. In a house occupied by
Major Fowler and myself in Mauritius, and surrounded by
trees, the Simuonis antipyrus was a pest by day, while C.
falcoin was equally troublesome by night. In the barracks
of the European troops, however, situated in an open grassy
mead a few hundred yards away, these insects were not
nearly so numerous. Many similar experiences might be
cited.

10. Houses.—Without making any general attack on the
numbers of mosquitoes in a locality, they can be reduced in
dwellings simply by the manner in which the house is built.
As a general rule Anophelines much prefer dark damp houses,
especially with wooden or mud walls and thatched roofs, and
surrounded by thick vegetation. Lofty houses built of stone,
with large windows and plenty of ventilation, are not so
haunted by Anophelines, though they may sometimes be full
of Culicides.
I am sure that the colour of the walls is a very important detail. No mosquitoes seem to like white walls and ceiling, especially if there is plenty of light (Nuttall, 1906). Europeans called upon to live in the tropics are very apt to bring with them their ideas of house decoration, and English ladies especially like to furnish their drawing-rooms with numbers of beautifulcurtains, pictures and stuffed chairs, all of which harbour the insects. This method of decoration is rather barbarous at the best, and is quite inappropriate for warm climates. Curtains especially check the breeze which is so cooling to the inmates and so unpleasant for mosquitoes.

The whole subject of houses in the tropics requires very careful consideration. The housing of the poor is often simply disgraceful. The building laws, if any, are generally evaded, with the result that the mass of the people have to live in the most miserable shanties made of wood, palm leaves, and often of old kerosene oil tins. In every malaria country a committee should be appointed to consider the whole of this housing question, especially with a view to excluding mosquitoes and malaria. Good houses suitable for the poor could easily be designed, and building laws could be made in order to enforce their construction by degrees. The same remarks apply to tropical cities, where the native quarters are generally in a dreadful condition. There is no reason which I can see why houses in the tropics should not be as well built as those in temperate climates. This, however, is a question of scientific administration in opposition to those forms of administration which we meet with too often in the world.

36. Prevention by Treatment.—It used to be said that prevention is better than cure, but we are now feeling that cure is one of the best methods of prevention. In all parasitic diseases, one way to remedy the disease is to destroy the parasites in the patients, who then cease to spread them to other persons. This has been undoubtedly the case with
The history of prevention by treatment in malaria is a long one. Laveran, in 1897, gave many interesting details. After the mosquito theory was established, Koch was the first to call marked attention to this method. He suggested that all patients, especially children, should be carefully treated with quinine. His principles were immediately tried in Italy and in various German possessions; sections 49, 52; and in Professor Coli's contribution to this book, an admirable account will be found of the use of the method with more recent extensions given by the Italians themselves. Equally good results are quoted by other contributors to Chapter VII, where many practical details are given.

As stated in section 33, treatment affects the malaria equation partly by increasing the recovery factor, and also by reducing the proportion of infected persons with gametids in their blood. It thus modifies two of the factors. Treatment of the sick only should be called case reduction; and treatment of those who have not yet shown symptoms, but who may have become infected unknown to themselves, should be called quinine prophylaxis.

We should always understand that quinine does not really prevent infection. I presume that the protozoans may be inoculated into a person whether he is taking quinine or not, but that they will not thrive in the former case—see negative cases 5 and 6 in section 15. We should also understand from section 23 that quinine, whether used for case reduction or for prophylaxis, should be continued for a long time.

The drug does not have a very lethal effect on the gametids, at least those of the malignant parasites when these are once formed; but it certainly tends toward destroying the other forms. The Italians insist that it does not have much effect upon relapses, but, for reasons given in section 25, I doubt...
PREVENTION BY TREATMENT

whether they are right on the point, and am inclined to think that the inadequacy of the treatment has been to blame for the recurrence of fever. This point is made clearer by some of my cases recently studied in Liverpool by enumerative methods. On the whole, there is no doubt whatever that a continuous and sufficient use of quinine will tend largely to reduce the malaria ratio.

Another point must not be forgotten. For public health work cases cannot be treated with the elaboration of detail employed in hospital practice. All we can do is to recommend a general line of treatment for the public; and, in fact, the people must become their own physicians. It is idle, therefore, under these circumstances, to suggest complicated scales of dosage and the use of various preparations.

I have always taught, in entire agreement with Professor Celli, that daily dosage is much the best for public health work. He insists strongly that physiological immunity of the patients against the drug is much more quickly arrived at by daily dosage than by intermittent dosage—and I have always found the same. But there is a still stronger reason for daily dosage. If we order quinine every few days, the patient is apt to put off the evil hour until to-morrow—he complains that he has much work to do to-day, or that he has indigestion, or is not feeling very well. When to-morrow comes other excuses may be found. Then the patient is attacked with fever and finally decides that the quinine treatment is of no use. Personally, I recommend that quinine should be given invariably once a day, either just before the morning meal or at bedtime.

With regard to dosage, I do not advise quantities which will disgust the people with the drug. It is perhaps better to use amounts which will prevent the disease only in a percentage of people than to cure all of them at the expense of making them all ill. Celli recommends 40 centigrams of the bisulphate, hydrochlorate, or bichlorate for adults and young persons; \footnote{See section 49, p. 417.}
25 centigrams of the same salt or 30 centigrams of the tannate for children; and in every case administered in the agreeable form of comfits or of chocolates. But he increases the dose to 50 or 60 centigrams for adults in the presence of very severe malaria. I have generally recommended 3 grains, 33 centigrams) for adults, and much similar doses for children. It has, of course, been shown that children can take quinine in larger doses than adults; but, on the other hand, I doubt whether such larger doses are really necessary for them, and the vomiting which is frequently caused in young children by the larger doses is apt to alarm mothers. In fact, we have to take the greatest care not to impose too great a burden on the people whom we wish to persuade into antimalarial courses.

In India quinine is generally administered for public use in the form of powders wrapped in paper. I think that this is a bad method, partly because the taste is so very apparent in powder, and also because much of it is wasted. I recommend freshly-made pills or tablets, coated in a suitable manner. If these are swallowed in milk or in water just before a meal, the taste of them does not remain in the mouth for more than a few seconds. Personally, I always take the drug thus in preference to chocolate, etc., in which the bitterness seems to me to be rather increased than diminished by contrast to the sweetness of the preparation. Small children can generally be bribed to take a pill by giving them some small article afterwards.

The experiments on the absorption and elimination of quinine (section 23) cannot be accepted as having answered the question as to which is the best salt for use in treatment or prevention. For this purpose accurate observations by enumerative methods, such as we are now adopting, must be carried out at length. The only answer to the question can be obtained by finding exactly how many parasites are killed by a given dose. I have usually recommended the more soluble salts, because a greater quantity is likely to be found in the blood at a given moment; the insoluble salts are certainly
absorbed very well, but probably not so suddenly as to produce a maximum poisoning effect on the parasites. On the other hand, the insoluble salts are likely to keep the blood more continuously intermingled with the drug, and may therefore be more useful for general prevention. Pending such researches, it cannot be said that one salt is much more efficacious than another; and the salts selected must depend upon the local price, and the local facilities for making up any form useful for administration. The sulphate is certainly the most generally used in British possessions, but the Italians have lately insisted very strongly upon the tannate, which certainly has great advantages, being nearly tasteless and comparatively cheap. Its use is more expensive, and it is generally prescribed in doses of 50 centigrams for adults and 25 centigrams for children.

Arsenic was used long ago for prophylaxis by Tommasi (Trudel), but has now been abandoned in Italy. We are making further experiments with atoxyl and methylene blue. It would be most useful if some drug could be found which affects crescents more definitely than quinine does.

Various other agents, including serum of cattle, have been tried, but the experiments will have to be repeated by concomitant methods.

Segregation.—On going to West Africa in 1899, after service in India, I was much struck by the fact that Europeans in the former country were not segregated as they are in the latter. In India the British officials and troops are nearly always housed in separate locations commonly called cantonments, so that they are frequently spared infection derived from neighbouring crowded native quarters. But in Freetown, Sierra Leone, the officials were obliged to live almost in the midst of the native population, even ladies being housed in rooms under which native shops existed. I called attention to this immediately, and attributed much of the large death-rate amongst Europeans to it. The idea was elaborated by Stephens and Christopher, who added the important consideration that native children are
the principal sources of the parasites and J. E. Dutton strongly recommended segregation for Bathurst. Others opposed the idea, because they thought it would be wicked for the Europeans to live apart from their coloured brethren.

At this time the advisability of reducing mosquitoes was much discussed on the ground that the insects diffuse themselves in all directions from a breeding centre, just as particles of gas diffuse themselves from a surrounding liquid—which is, of course, not the case. At the same time segregation was much urged as an alternative measure; but I pointed out [page] that both the measures depended upon the same principle—namely, that mosquitoes do not diffuse themselves without limit from a centre. That is, I suggested the principles of random scatter given in section 29. Obviously, if mosquitoes spread to great distances, local drainage will not reduce their numbers, and, equally certainly, segregation will not enable us to avoid them. If this were the case, mosquitoes infected in native villages would be able to travel to such distances that segregation would be useless. Happily, however, this is not the case, and therefore both segregation and mosquito reduction remain valid.

We may segregate ourselves from the proximity either of many infected persons or of breeding places. S. E. James [1901] removed a number of people from a locality in which Anopheles abounded and in which they were not scarce. In October 1901, seventy-eight children belonging to those people showed malaria parasites in 5%. In August 1902 they were all moved into tents about 600 metres from the nearest pool—no Anopheles now being found in the tents. The result was that not a single case of fever occurred among the adults, and that on 24th October the height of the fever season, parasites were found only in one out of twenty-five children examined—and this without treatment of any kind. Their spleen rate had also decreased from 75% in April 1902 to 60% in October 1902—the splenomegaly evidently disappeared much more slowly than the parasite index.
As proof of the good effect of segregation from infected persons, I think that I may safely quote the case of the Indian cantonments, where malaria is certainly much less than in the crowded native quarters in the neighborhood. Similar segregation has recently been carried out in Sierra Leone, where a special quarter has been provided for officials at some distance from the native quarters, I believe largely to my advice given previously.

I look upon segregation as a most important measure for preserving the health of European officials, not only against malaria, but against many other diseases. It should always be adopted until sanitation in general attains a much higher degree than it has hitherto attained.

37. Selection of Measures for Personal and Domestic Prophylaxis. The various preventive measures have been described in the previous section as briefly as possible, because much more information is given in the important contributions to this book contained in the following chapter. But we must now discuss exactly an important matter, namely, the relative value of these measures for use under various circumstances. The preventive measures themselves are now well known, and are described in all the text-books; but more description is not enough, as it is always difficult to employ every one of the measures, and both the individual and the health officer may be called upon to select the most feasible ones. We have to examine, first, the measures most appropriate for the individual—that is, for private persons, heads of houses, factories, institutions, ships, and so on; and, secondly, the much more complicated problem of the selection of methods for public prophylaxis.

1. Self-protection of Europeans in the tropics—I have had experience on this point during many years and in many different countries, and have only once been infected, and that at a time when we did not know how the infection is produced.
PREVENTION

I always rely upon the possession of four articles, namely, a good bed-net, costing about eight shillings, a small hand-net for catching mosquitoes, costing about one shilling, a palm leaf fan, costing one penny, and a bottle of quinine. With these articles the chances of becoming infected are reduced enormously—especially if a little common sense and care are added to the stock.

I cannot speak too highly of the ordinary bed-net, as directed in section 54 et seq. Anopheles almost always bite at night. If the number of bites received by two individuals, one of whom always sleeps in a bed-net while the other does not do so, could be strictly estimated. I think it would be found that the latter receives only about 1/10 of the number of bites inflicted upon the other. When a person is walking about in the day or in the evening, he is not nearly so accessible to any species of mosquito as when he is still and unconscious in sleep. It is therefore almost certain that the large majority of inoculations occur during sleep, and hence, obviously, protection during sleep will prevent a very large proportion of them.

Moreover, I have frequently found that persons who despise bed-nets, as many sportsmen, soldiers, planters and others are apt to do, are very prone to suffer from malaria. So are those who use bed-nets carelessly. After service in India, where most people are wise enough to guard themselves in this manner, I was much struck by the negligence on the part of Europeans in West Africa. There can be little doubt that the comparative good or bad health of Europeans in many parts of the world depends very much on the intelligence which they display in this matter—which seems such a small one to thoughtless people. Fortunately, the public have now been awakened, and I have even heard of several shipping and business firms who are wise enough to hold their employees responsible for becoming infected, unless they can show that they have used every precaution. This would be a very good plan to adopt generally, even by governments and military authorities.
Next to the bed-net, I attach most value to the small paddle-hand-fan, as stated above, I much prefer the use of it to thick gloves, mosquito-boots, etc. Here again, the more plainly, but often more serviceable, is apt to dispense with common sense.

The small hand-fan is almost equally valuable. If I sit down to write or read, I am generally worked at once by a number of hungry insects, and I like to take the precaution of catching and killing the 6th before proceeding in any task. In fact, I am not ashamed to confess that I have both a hand-net and a hand-fan to bed with me, in order to deal with any flying insects which may enter with me.

Prevented by these humble means, I do not often have recourse to quinine. In most places in the tropics where large numbers of biters are collected, or lives, the continual use of quinine is severely demanded. But example, in the Indian cantonments or the principal towns and settlements in other tropical countries, the chances of infection are too small to compensate for the discomfort caused by the drug, even when given in the best form and in the best way. It is, however, another matter when one is obliged to sleep in places of high prevalence, and bowls we should always use the drug. Medical men can often be guided also by the great prevalence of Anophelines, and in fact many of the general public are now beginning to recognize these dangerous insects by their attitude and the spots on their wings. If exposed in this manner, or if I think that I may have been bitten by infected mosquitoes, I take the drug daily for about a fortnight or more (between 30-50 grains or 1 3 to 2 3 grammes). I know that this will not absolutely destroy destruction of any pre-existing which may have entered, but I trust to luck that this has been the case. Anyway, I think that the inoculated germs have been so much reduced in numbers that for certain reasons of my own, I think they are not likely to produce a very severe illness.
even if they do reach the fever limit. Then also I am otherwise protected by netting.

...
great value. Malarial infection of Europeans is very rare in
India and Ceylon, where they use pushkas almost day and
night, but it is common enough among planters, who are apt
to neglect them. I really think that pushkas prevent some-
thing like 80 to 90% of infection. Moreover, they keep the
body cool and vigourous while without them we remain fevered
with perspiration and tormented by mosquitoes all day long.
So convinced am I of the value of pushkas or fans by general
hygienic reason that I would advocate the use of them even
in those where every mosquito has been banished.

The question of prevention for European children in the
tropical is of the greatest importance. The difficulty ofExcel
them is due, I think, partly to the great heat, partly to malaria,
and partly to various external and other diseases. Those who
exposed to weather and pushkas should therefore employ them
for their children at whatever cost. If they cannot afford them,
they should use their children to the pushkas. The habitual
use of prophylactic quinine is seldom seen among European
children in the tropics, and I doubt whether it can be generally
be recommended. In fact, if such one is actually required, the place
should be considered too unhealthy for children. On the other
hand, the American troops in the Philippines used
nets and admitted their great value. Where the authorities
fail in providing them the wise soldier will do well to follow
the old maxim of “self-help.” A daily quinine ration of say 3 grains
every morning should also be insisted upon, together with the
rigorous use of nets. I scarcely think that gloves and veils,
such as Lawrence figures as used among the Japanese troops,
are so urgently demanded—at least in the tropics, where they
would be nearly intolerable. The Medical Department has the
care of choice of proper bivouacs and quarters.

4. Ships.—I always carry a net which can, if required, be
hung over the deck. Ships in the tropics often delay for
hours on days in port and are frequently visited by swarms
of mosquitoes. Of course, all ships owned by companies who
 preserves any degree of humanity and intelligence should be
immediately screened against mosquitoes in the manner shown
by Dr. Alexander Thomas (section 4a).

Quinine should always be given to the crew on arrival at
the first malaria port, and for at least one month after
leaving the last one, if the voyage lasts so long. The great mistake
of stopping the drug on departure from the malarial coast is
often made generally. Many of our medical patients
in Liverpool give histories of having been attacked for the first
time when nearing the British coast—that is, their infections
had been received weeks previously, but had been suppressed
by the drug until the use of it was abandoned.

5. Hospitals and Asylums.—Here quinine cannot be given
without interfering with the treatment of the vast amount
of disease present. The superintendent must see to it that
mosquitoes are not being bred within the hospital premises,
but unless mosquito-reduction has been adopted for a con-
siderable radius outside the institution, screening should be
adopted as well. Hospitals with crowded, unprotected wards
 furnish the worst example of congested sleeping (section 28
10), so favourable to the mosquito transmission of several
diseases. For example, dengue prevailed greatly in an un-
protected hospital in the Philippines, while it was absent from
a protected one; and I have frequently found dengue and

* See destruction of adult mosquitoes, p. 326.
plasmodia in hospital mosquitoes. In fact the dangers are so
great that it is perhaps better to advise that every hospital
should be screened whether mosquito reduction is carried out
or not. A mosquito-infected hospital is a most disgraceful
thing. The miserable defenceless people it contains are in-
fected in the very place where they have come to be cured,
and there is no excuse for it.

C. Barracks.—Unless mosquito reduction can be rendered
efficient, the best plan is perhaps to employ screening as
well. Probably most of the inoculations occur at night largely
in consequence of the congregate sleeping usually adopted in
barracks. The cost of death and invaliding of soldiers is
probably far in excess of that of screening. Bed-nets are now
being much used or advocated, even for native soldiers, and I
have heard of several cases where officers have helped their men
to procure them. But surely it is the duty of the military
authorities to provide screening instead. Estimations are
freely wasted on the erection of new barracks which
would have sufficed to screen all the barracks in a country.
The neglect on this point is simply marvellous. In one case,
known to me personally, a serious epidemic of malaria started
because the authorities were disputing as to who should pay for
the huts required to hang the bed-nets already purchased.
Several of the men died, and a number were invalided at a cost
which (considered) sufficed to drain the whole neighbourhood.

Parasites killed by machinery have long been in use in many
military hospitals and barracks in India.

Unless screening is very perfect, great care must be taken to
complete the extermination of the parasites in infected soldiers.
In any case this is necessary in order to maintain the effec-
tive fighting strength, because soldiers “wrecked” with malaria
are only a source of expense in war. I doubt whether the
six weeks’ treatment used in India is quite sufficient.

Of course a large proportion of the infections among troops

are often contracted outside barracks. The question then becomes one of public prophylaxis (section 39).

The quarters of officers and families should, in my opinion, be always screened unless mosquito reduction is very perfect.

In the old days in British possessions, large areas of barracks were kept entirely under the cantonment authorities, who refused to allow the general populace to live in them. Unfortunately, owing to the sentimental notions which are proving so destructive to vigor and prosperity, this wise rule is now beginning to fall out of use. Fly nets spring up close to the barracks; the troops become heavily infected with malaria and other diseases, and the nation which gives way in this, however reluctantly, has to pay much more for its military service, and may have to pay still more some day, for military credit.

17. Prisons.—The prisoners are taken from the lowest possible level and are being constantly charged as sentences expire. Hence large numbers of them are infected outside, and the principal measure is case reduction. In addition to this, screening or mosquito reduction, or both, should be adopted according to circumstances.

18. Schools.—Boarding schools are scarce in malaria countries. Day schools give a most valuable opportunity, not only for dealing with malaria by case reduction, but also for measuring it; but this matter is part of the general plan of campaign (section 40). a

19. General rules.—In all matters of domestic prophylaxis it is wise to remember the following rules which cannot be repeated too often: (a) unless there is strong reason, it is better to believe that cheap measures must fail; always begin with them before attempting more expensive ones; and (b) do not adopt any measure until careful examination has proved the necessity for it. For example, I have seen and heard of expensive screening being installed (a) where a little mosquito brigade work would have cleared the mosquitoes entirely, and (b) where most of the infections were really being acquired outside.
38. General Sanitary Axioms.—Before we consider the complex subject of public malaria prevention, it is advisable to state the following series of propositions regarding the prevention of all diseases.

1. Widespread diseases, especially endemic diseases, cause much pain, sorrow, expense and loss of property to the people.

2. Next to the maintenance of the State, it is the duty of scientific governments to investigate the mode of propagation, and to endeavour to control them.

3. For economic reasons alone, governments are justified in expending for the prevention of such diseases a sum of money equal to the loss which the diseases inflict upon the people.

4. The amount of money spent on the prevention of various diseases should, when possible, be proportioned to the amount of sickness and mortality caused by each.

5. It is the duty of governments to make and to enforce ordinances required for the prevention of diseases, and of the people to submit to them.

6. Certain prohibitions that sanitary measure is the wisest which causes the public the least inconvenience.

7. Certain prohibitions that measure is the most practicable which can be carried out by governments without making any demands at all on the thoughts, efforts or compliance of private persons.

8. Certain prohibitions that measure is the most essential which enables, for unit of cost, the widest benefits on the public.

9. For the prevention of diseases on a large scale a suitable expert organisation is always required.

10. It is always advisable to carry out accurate and repeated measurements of the prevalence of the disease which we propose to prevent; of the cost of the adopted measures and of their results.
Written out in this manner these statements appear trite enough; but in my experience every one of them is forgotten in actual administration. Thus few persons remember the first axiom—until they themselves are taken ill. Few governments really attend to the second one. Nearly any one has conceived the simple idea contained in the third, and it is the rule to prize spending a hundred pounds for a disease which costs thousands. Dramatic diseases interest many, while common ones are forgotten; and the remaining axioms are too often overlooked even by those who direct or discuss sanitary work.

59. Selection of Measures for Public Prevention.—From the fundamental maxim, in sections 29 and 33, and also from general experience in many countries during the last ten years, we are now probably justified in making the following statement: That malaria can be completely exterminated in a locality by the complete adoption of any one of the three great preventive measures, namely, protecting, mosquito reduction, and treatment. That is to say, if every person in the community were fully protected against mosquito bites, or if every multiplication could be hindered, or if every infected person could be thoroughly treated from the beginning of the case, then each of these measures ought to suffice by itself to check the disease entirely. Moreover, if we could use two of these measures, or all of them, the result would be still more assured.

But obviously, it will never be possible in any general community to adopt or to enforce any one of these measures completely. Thus, however carefully mosquitoes or screening are used, many people will still continue to be bitten occasionally, so long as the mosquitoes are allowed to remain. Again, however carefully we may destroy every mosquito which we can catch, or every larva, or remove the principal breeding-places, still a few insects and breeding-places are sure to escape us. Thirdly, however strongly we may urge suitable treatment of all infected persons, a few are sure to resist it, and to
spread the disease if any Anopheles are left. Hence, though theoretically possible, the complete use of any one of the measures is not really practicable.

Fortunately, however, we can see by careful consideration of the principles laid down in section 29 that complete eradication of malaria may still be possible by the adoption of each measure by itself, even if that measure is not completely given effect to. By that section we see that the static malaria situation will tend to vanish, not only if all the factors of the equation are rendered absolutely prohibitive, but also if they are reduced to a certain figure; that is, if the new infections can not begin keep pace with the natural recoveries. This important and encouraging law has been well exemplified in Great Britain, from which the disease has entirely disappeared in one partial and indeed almost unexceptional agency, as described in section 29 (2).

Lastly, we can understand from the same reasoning that a partial adoption of any one of the measures, though it may not banish malaria absolutely, is still likely, or indeed certain, to make some reduction in the disease provided that the other factors remain unaltered.

All these truths still continue to apply if we adopt not one single measure, but several combined. This, it may well be, that an extremely partial application of two of the measures will produce results as good as a less partial application of one of them would have done; and this fact may help us to do the work much more economically.

Thus the head of a sanitary department who intends to carry out a large campaign is fortunately able to select himself of several measures or combination of measures, by any one of which his purpose may be effected. But he has to consider means as well as objects: his duty to his Government demands, that he should spend as little money as possible, and his duty to the people demands, that he should not trouble them too much. Still more important, the various measures are more or
less practicable according to a number of local conditions, all of which must be carefully considered by him before he comes to a decision. In practical sanitary policy, therefore, the mere enumeration and general description of the various measures are quite insufficient, and we are obliged to discuss with great care their relative values under different circumstances. The reader can assure himself still further of this, by studying the numerous contributions given by the most eminent men in the following chapter. He will see that different measures are being adopted in different countries. In some countries, especially Southern Egypt, Burma and the Federal Malay States, re-plantation is the principal measure. In others, especially Haiti, Greece and the German and French possessions, prevention by treatment is the favourite remedy, and in other places combined measures are used. In fact there has been much discussion upon this point during the last ten years; some urge one measure and some urge others—each being guided by his own experience in his own miscellaneous country. The truth is that all the measures are good and useful, and that each is most suitable under certain circumstances. The subject is evidently a complex one. I will try to make the issue as clear as possible by supposing at first that each measure is to be adopted by itself alone.

Protective section 34 requires the use of bed-nets, screening, fans and some other devices. It diminishes the extent of recurrence of the people who are to be protected. Probably no government can force the public to protect themselves. Although the rich may be quite willing to do so by bed-nets or screening, the poor will generally refuse the expense incurred. The cost of a good bed-net is, for instance, equal to the monthly pay of a day labourer in India. The cost of screening a house completely is often more than a tenant cares to incur, and the house owner generally refuses to undertake it for tenants who occupy their houses on short leases (as generally happens in the tropics). Fans and nets are scarcely
practicable for the poor, and medicinal calomel is of little value. In many countries the poor, especially in rural districts, are badly housed in huts which are everywhere permeable to mosquitoes. To protect such huts by any known means will generally cost as much as rebuilding the whole house. Even if the state were willing to provide even houses like this with a bed-net for himself and his family, it would still have to make arrangements for the constant renewal of them, while they would often remain unused. We can scarcely expect that poor families, living crowded together in a single chamber, will ever consent to use mechanical protection in a correct way. But even with the most complete protection of houses, people will still be subject to being bitten outdoors.

This, however, is to look at the subject only from the outer side. As already stated, even a partial protection is quite likely to have an immense effect on the malaria. Even if only a proportion of the people could be persuaded to use any one measure in protection, it is clear that the new infections would be reduced so much that the static malaria might either disappear entirely or become very small. It is, therefore, most advisable to urge protection as strongly as possible to advocate suitable housing for the poor, and to post notices for the information of the public regarding the dangers of being bitten by mosquitoes.

We see, then, that the measure of general protection against mosquitoes is probably capable of more than a very partial adoption by the public. As a Government measure it is opposed to the seventh sanitary axiom given above. Although it possesses what some governments may consider to be an advantage, namely, that it does not make direct demands upon their own finances, it may yet be in the end more costly to the public than other measures. In most countries the number of houses is equal to about 1 4 or 1 5 of the total population—that is to say, the houses are very numerous. The cost of screening each house or of providing all the inmates with mosquito-nets will therefore mount up to a very large sum. Thus in a city
of 30,000 inhabitants, there are likely to be 6,000 houses, and if the average cost of screening each house amounts to only £1, the total cost, including that of maintenance, will be very large. I doubt whether any form of screening for the poor will not depreciate at the rate of 10% per annum. It may therefore happen that the total cost will greatly exceed that of mosquito reduction or treatment. Even if it does not exceed that of mosquito reduction, the advantages of the latter are so great that it would be preferable to adopt it if it is feasible.

So much for protection as a general measure; but it is often decidedly called for under special circumstances, as for isolated houses in the country, especially in proximity to marshes; and for boats, barracks, private hotels, travellers' rest-houses, tents, ships, river-boats, and so on.

For general prophylaxis, especially in coiled facilities, Anopheline reduction has many great advantages, which I have often pointed out. Practically, Anopheline reduction may be generally merged into the wider measure of mosquito reduction, which costs little in respect and adds greatly to the benefits obtained. It is essentially a radical measure, which tends to remove not only the carriers of the disease but also a continual source of annoyance to the public. As mosquitoes are known to carry other diseases, namely, yellow fever, typhus, and almost certainly dengue, mosquito reduction will probably do much more even than to relieve malaria. To the general hygienist it has still greater claims for consideration, especially because it conforms perfectly, not only with the eighth sanitary axiom, but also with the sixth and seventh—which is not the case with some of the other measures. For example, a government or municipality can maintain men for the purpose of removing breeding-places without causing any trouble at all to the popular. A certain amount of legislation is required to control obnoxious people who sometimes refuse out of wilfulness to allow sanitary agents into their premises; but beyond this it is generally advisable for the authorities to do everything as
regards mosquito reduction for themselves. No one is asked to
believe in the mosquito theory, or to take drugs, or to protect
himself and his family with bed-nets, or to put screens on his
windows. Nor does mosquito reduction cause much or any
inconvenience to the public as a whole. Occasionally cultivation
in paddy fields must be controlled, and pets, carrier,
wells, etc., used for irrigation must be dealt with, but compulsion
for any harm done must be paid for by the authorities
and, where mosquito reduction is generally feasible, only a
small proportion of the people are affected in such matters.
Lastly, mosquito reduction has the advantage which is not
always recognized, that it implies the sanitary authority's
willingness to maintain a minute inspection of the area under
their care,compulsorycleaningofallpaddies,removalofmud
water, proper maintenance of wells, and so on. Section 2.
Practically, however, questions of cost and feasibility have
to be considered. It is almost impossible to give an estimate
of the cost of mosquito reduction, which may depend every-
where on the nature of the soil, the slope of the ground, the
rainfall, the vegetation, the existence of marshes, the character
of the drainage and of the sanitary department already in use,
and so on. Quite possibly, although the necessary expenditure
is really within the capacity of the local budget, the authorities
may not think it at the moment, so that the health officer
is left_puzzled to adopt this measure. The advantage of
mosquito reduction is that it can be carried out entirely by the
state, without the corresponding disadvantage, namely, that the
state imagines that it alone pays for the work. In a perfect govern-
mental machine, the state could immediately call for increased
taxes in consequence of any work of absolute public necessity;
but in this very imperfect world, the public is apt to be rather
blind in these matters, and the state is afraid of arousing
hostility, even by saving people's lives. At the same time it is
proper to note over and over again that mosquito reduction
often really does not cost as much as some pretend. The
figures for Ismailia and the Federated Malay States include large items in excess of the actual anti-mosquito campaign, that is, items for general drainage, for building sites or cultivation purposes; and these for Panama are so mixed that we cannot exactly estimate the cost of this measure by itself. Moreover, by the general principles of section 26, malaria may be completely relieved even by a partial reduction of the Anopheline below the necessary limit which I have roughly estimated to be about 20 different Anophelines per head per month; and it may be partially relieved even by a smaller reduction of the insects. In fact the small measures under the head of minor works generally cost but very little, and though they may not suffice for complete mosquito reduction, are still likely to do much good, especially if combined with other precautions.

Prevention by measures also has many advantages. In every locality, even if every mosquito can be halved, a number of cases are likely to continue to suffer from relapses for many months, and these always require careful treatment. Hence case reduction should always be adopted as much as possible whether the other measures are used or not. Such case reduction can hardly come within the sixth and seventh sanitary provisions, because the experience of Panama is reflected on the people by gratuitous treatment of their sickness. Another great advantage is that the measure can be continued, even on a somewhat large scale, by medical men, without making any immediate large demands on the public purse. As shown in Italy and Greece the more sides of quinine at a cost prior to Government produces an excellent effect, if the people are intelligent enough to use it. Moreover, medical men who are now best acquainted with the whole theory of malaria are probably those who carry out this measure, in fact their practice actually receives some benefit by it, at least at first; they are accustomed to the use of drugs, and they find no difficulty in urging their patients to take quinine.

\* Col. Sturey says it is a fact (see p. 99).
Unfortunately, all this does not apply in many countries in which the number of qualified medical men is very small. In many other countries the natives object entirely to our forms of treatment, and deal very much against opinion. Still further, many people are afraid of admitting the existence of domestic illness and will not take the trouble to treat them at all. Others, again, refuse to buy quinine, even at the cheapest rates, or cannot afford the time to attend hospitals or dispensaries for it, so that inefficient doses are frequently taken, with the result that the patients lose all appetite as to the value of the drug, and advise their friends against it. In fact, these practical difficulties are so great that, as I stated in my Mauritius report, we are driven in the main to administer the drug gratis from house to house if we wish to obtain any material benefit from it. Lastly, if we pretend to undertake a scheme only to cure relapses, it is evident that, as to the treatment of the case, we have to distinguish the sick in the healthy, which precisely can be done only by medical men or by qualified auxiliaries at the cost of considerable and continued labour.

It is, therefore, not only if the public can be persuaded to accept it only as medication, but also to some prophylaxis—but in the treatment of persons who have not yet shown signs of illness, but may possibly have become infected. Until very recently there were difficulties in the way of treating the sick; there are sure to be still greater difficulties in the way of persuading healthy persons to take any form of quinine continuously. Poor and ignorant natives and indeed many other people object strongly to this course. If we say that they would normally prefer the occasional chance of malaria to a continued certainty of dysentery. It is true that if quinine is given daily in small doses it produces much less physiological effect; but in the majority of cases it always does produce some slight inconvenience. Busy people, hard-worked labourers or mothers of families tend to rebel very much against any continued
We know how much people are apt to protest against vaccination—a simple operation causing scarcely any discomfort, and protecting for years against a disease as terrifying as malaria. How much more therefore, they reason, if they are not affected by the disease. Of course, persons in danger should take the necessary precautions, and for this reason alone a difficult task—the authorities have such power that they can actually force the drug down the throat of the people. This is often possible in the case of soldiers, employees of companies, or children in trade schools, but hardly for the general public.

On the other hand, we may not dismiss, though complete case reduction is seldom practicable, that the partial reductions certainly do much good. Because we cannot force all the people to take quinine, that is no reason why we should not persuade as many as possible to do so.

Measures, either from mosquitoes or from infected persons, should not be looked upon as a measure of general public protection, as it is applicable only in a few cases. Next, let us consider the measures two and three—viz., the risk of repulsion. First, suppose that we have a colony where all the mosquitoes are equally mobile, and will cost the same sum of money—a thing which, of course, never happens.

Protection is evidently at a disadvantage compared with mosquito reduction. It will never entirely prevent the bites of mosquitoes; nets and screens always require some trouble to keep in order, and certainly add somewhat to the heat—often unbearable in the tropics. On the other hand, mosquito reduction, if sufficient, removes at once an incubus, a veritable plague—we breathe, move and sleep freely, our children are free, our verandas and gardens open to us.
Now, compare protection with prevention by quinine. The former guards us not only against all mosquito-borne diseases, but against constant personal annoyance, the latter, only against malaria. Nets and screens cause no dyspepsia, no ringing in the ears, and no daily trouble with the children. I think that every one will prefer freedom both from mosquitoes and from dyspepsia to the inflictions of both. Hence protection has great advantages. But, in spite of this, the sick must still be treated.

Mosquito reduction has all the advantages of protection and more, and is therefore greatly preferable under our hypothetical conditions to quinine. But, nevertheless, the sick must still be treated.

Ideally, therefore, mosquito reduction is by far the best measure. Protection is next, and quinine last.

Now let us consider the measure from the point of view of cost and feasibility. The cost of protection must obviously vary according to the number of houses, which can be roughly estimated by dividing the population by about four or five. In Mauritius at the census of 1901 the population was 57,336, and there were 35,071 houses, so that there were about 2,553 persons to each house on the average. Probably the cost of protecting a single house there would be quite £1 on the average, as a very low estimate, amounting to £35,071, about £12.500,000, for the whole island. Besides this, repairs and renewals of the screens and nets would probably amount to quite one-third of the original cost at a low estimate, so that after the first installation of the protection an annual cost of £3,700, 15,000 rupees would have to be incurred for the mechanical work of supervision. This, of course, is a very rough estimate, and quite possibly more than £1 would be required to protect each house on the average, because many of the poorest houses are little better than shelters of mud and thatch. Regarding the feasibility of protection, I repeat that it cannot be forced by Government on the people except as
regards employees of planters, railway companies, etc. Officials cannot, therefore, have any resource except to persuade and, to keep on persuading, and even then only a proportion of the people would adopt the measures. For anything like general protection the Government would probably have to supply most of the cost—which we have seen will be very considerable. Of course, in Europe and the United States, where the people have reached a higher degree of prosperity than in most tropical countries, this measure is more likely to be adopted by the general public; but even in them the very poor and the agricultural classes are likely to cause great difficulties. It can, therefore, scarcely be said that general protection, or even protection of a percentage of houses, is an easy and cheap measure. Observe, also, that the cost of it is likely to vary according to the number of houses.

Notes on the cost of mosquito reduction have just been made. For Mauritius, which contains 705 square miles (1,804 square kilometres) and a population of 534 persons to 1 square mile, I estimated that a general mosquito reduction in inhabited areas, especially in towns, would cost, for minor works alone, the sum of £5,000 (65,980 rupees) per annum. For making this estimate I relied upon figures given to me by the Medical Department, who suggested the number of workmen which would be required for each village, plantation, town and district, and the sum includes funds for the director, and travelling expenses. But it does not include the cost of the major measures, that is, the drainage of large marshes, and dealing with such waters as require the advice of an engineer—section 35 (c). This cost was estimated in Mauritius by the Public Works Department at a capital expenditure of about £42,000 (630,000 rupees), but I advised that these major works should be undertaken only where the minor works might be found, after experience, to be ineffective.

For the reasons already given it is almost impossible to furnish any general estimate for mosquito reduction anywhere.
The cost depends upon the number of major works required, the price of labour, the price of expert supervision, the local laws, and the local efficiency of administration. It is very difficult to extricate from the accounts of various campaigns the money expended on mosquito reduction alone. In the town of Port Said, however, where there is very little rainfall and where a complete Culicine reduction has been carried out, the cost has been about 5d. per head of population per annum (section 53).

I have already stated that mosquito reduction has the great advantage that it can be carried out by Government alone without reference to the people. Labourers can be employed to treat Anopheline waters or to clear away Culicine waters from the backyards of houses, without causing any real trouble to the public. It is not necessary for Government officials to go about persuading householders to do this or that, or for medical men to examine large numbers of individuals, and so on. On the other hand, mosquito reduction may just possibly be essentially unfeasible in places where the breeding waters are such that they cannot be removed for any cost that can be afforded by the local funds; and this is, of course, a question upon which it is impossible to make general statements.

As a broad rule the cost of mosquito reduction must always tend to vary according to the area of the country treated.

It is often thought, especially by medical men, that the cost of prevention by treatment is almost nil. We write prescriptions, which cost us nothing and which are made up by the dispensary; and we often seem to think that a similar prescription can be given, at the same small cost, to a whole nation. But the cost is sure to be very considerable. For Mauritius, in addition to the mosquito reduction, I prescribed a very partial scheme of prevention by treatment, costing 3,000 rupees for the quinine alone, 3,000 rupees for its preparation and despatch, and 6,000 rupees for the services of five quinine dispensers, amounting to £240, or 32,000 rupees, per annum.
This was without the salary of a director and cost of office, etc., and it was proposed that the quinine should be distributed gratis, but chiefly in intensely infected localities.

Here again the cost must always depend largely upon the local conditions. A highly civilized and prosperous people will take the drug readily, where a very ignorant, poor, coloured population will require the utmost amount of persuasion. Thus we have to pay not only for the amount of the drug used, and for its preparation and despatch, but also for an agency which will distribute it to the people and will persuade them to use it properly. We are very apt to forget this last and very costly item. Think for a moment of the position of the very poor in malarious villages and towns. The servant of each house is generally obliged to go to his labour extremely early in the morning. His wife has her household duties and her children to assist in. What time have they to obtain the drug at 5 o'clock—perhaps which may perhaps be miles distant, and, very often, what money have they to purchase it with at all? Moreover, neither the man nor the woman has time to force the medicine down the throats of the younger children. The same difficulties recur day after day and week after week, perhaps during the whole of the malaria season, and even beyond it. Meanwhile patients rebel against the medicine, just as much as those who care for them rebel against the necessity of taking it, and soon there is very apt to be a general refusal. This has been strongly felt already in many localities, where prevention by treatment has been much practised; and in fact it was for this reason that my advice was sought both at Simla and in Mauritius. Dr. Malcolm Watson has also made some important remarks under this heading, section 57.

In my Mauritius report I laid down that for most tropical countries the only effective way of giving quinine is to give it gratis, to give sufficient quantities to last each patient for one or two weeks or more, and (2) to distribute it actually from house to house. Now all this must cost the State a very
considerable sum. As a matter of fact a large number of fully qualified medical men, and also qualified assistants, must be employed to carry out this distribution, and we must remember that the salary of a fully qualified medical man is as much as the wages of about fifty coolies at least in India, and the salary of a reliable qualified assistant may amount to as much as the cost of five or ten coolies.

Regarding the feasibility, independent of cost, we must again remark that this measure does not accord with sanitary points 6 and 7.

The cost will tend to vary according to number of population.

To sum up—prevention is evidently a prior and domestic measure which cannot be forced by any government on the people unless the former is willing to supply the nets or screens in the latter—the cost of which would probably largely exceed that of mosquito reduction, at least in towns. But protection should always be adopted for public buildings and isolated houses, such as railway stations, rest-houses, and bungalows on estates. I think that it might also be used even at the cost of supplying nets for villages in proximity to large marshes which cannot be drained without great expense. At the same time it should always be urged on the public by means of lectures, pamphlets and placards which cost Government almost nothing, and certainly have a good effect.

Practically, therefore, for public prophylaxis we are called upon to choose between mosquito reduction and quinine. Ideally the advantages of mosquito reduction are simply overwhelming—so much so that I urge it should be universally adopted in all towns in the tropics, as a part of a general crusade against vermin of every description. The relief caused by removal of the mosquito pest is great enough to compensate for the small cost involved (in towns) even if the insects do not carry any disease.

Practically, however, our choice is often limited by the financial position of the place and time. To familiarise him-
self with the question the reader will do well to recall to his memory various localities which are well known to him. Suppose, for illustration, that malaria were to break out in London round Hyde Park in consequence of an obstruction to the drainage to the Serpentine river. Can we suppose for a moment that the authorities would not at once undertake Anophelean reduction by removing this obstruction? Would not this be much cheaper and almost infinitely more convenient than to force people to screen their houses or to take quinine, while the hypothetical mosquitoes are allowed to remain as numerous as before? Precisely the same answer must be given in the case of most cities, towns and even large villages in the tropics. But now take another extreme case, and suppose that the disease were to break out in any large rural area in Europe, such as among the bogs and lakelets of Connemara. What practical hygienist would urge mosquito reduction here, with the immense cost involved, merely for the benefit of a few scattered farm-houses? The appropriate measures would obviously be protection and quinine, as a general rule; but even here, we might occasionally find villages in which the Anopheles breed in a few local waters which can be removed at a smaller expense than would be involved in the other measures. In fact, between the two extreme cases suggested, there are innumerable instances where either of the measures or both may be used, and where the director must use his own judgment.

The cost of reduction of Anophelean flies tends to vary with area, and not with population. It does not matter much whether the area is crowded with houses or not; though, if anything, density of population, necessitating well paved streets and the removal of agriculture, will tend to cheapen the cost per unit of area. Thus roughly, the cost of Anophelean reduction for a square mile of densely-crowded city or town is likely to be actually less than that of the Anophelean reduction for a square mile of uninhabited wilderness. In the former
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39] case the expense will benefit a large number of human beings, and in the latter case only the birds and beasts.

On the other hand, the cost of case reduction and quinine prophylaxis must vary directly, not with area, but with population. In the former case, the expense will benefit a large number of human beings, and in the latter case only the birds and beasts. Therefore, evidently mosquito reduction is called for by every consideration in the case of crowded areas, and, on the other hand, quinine tends to be the more proper measure amongst a scattered population, where Ampelamine reduction would be too expensive for the local funds. This is, of course, a general rule; exceptions to which must be carefully considered by the director himself.

Much thoughtless matter has been written on this point. For instance, it has been stated that because quinine has proved so beneficial in Italy, it is also the appropriate measure for all endemic countries. But the success of quinine there does not prove that mosquito reduction might not have been equally successful, possibly even at the same cost. It does not say that this is the case, but it might be so. Moreover, the conditions in Italy and elsewhere may be extremely different. Italy possesses a temperate climate which admits of mosquito-breeding only during a few months of the year, so that there is plenty of time for the treatment of old cases during the non-malarial months. Italy is also a highly civilised country with an intelligent white population, amongst whom there are numerous medical men who speak their own language and who add to their practice by the treatment of cases of malaria. Lastly, in Italy malaria occurs principally in rural areas, that is just where quinine is naturally called for. What more natural than prevention by treatment in it. But in many other countries these conditions do not obtain; malaria abounds in towns; the population is ignorant and often stupid; there are very few qualified medical men; infections occur nearly all the year round; and the cost of maintaining medical men and
dispensers for quinine distribution may, in urban areas, far exceed that, not only of Anophele reduction, but of mosquito reduction in general. We really must not apply rules suitable for one country to all other countries. We have to consider each case on its own merits.

Protection is a measure for individuals, mosquito reduction for local governments and municipalities, guided by their sanitary departments, and prevention by treatment for doctors. It is not to be wondered at that the last named are so fond of the last measure; they are acquainted with drug giving, but often not acquainted with public health matters, drainage and general municipal policy. They naturally tend to select quinine, and often very wisely so. In many cases, however, it would have been a wiser policy to have adopted the larger measure from the first.

Up to the present we have considered each measure separately; but in many cases, probably in nearly all, it may be better to adopt a combination of several measures partially carried out. In fact, practically it nearly always comes to this. As previously stated, the complete adoption of any one measure is generally impossible; we cannot remove every mosquito, nor can we treat every case. Possibly a partial mosquito reduction combined with a partial case reduction will produce the same amount of malaria reduction at much less cost. In other words, we remove what breeding waters we can remove without great expense, and we treat as many of the infected persons as possible. At the same time we urge protection upon the populace and adopt various methods under different local conditions. The proper policy is not the protection policy, nor the mosquito reduction policy, nor the quinine policy, but an opportunist policy which uses any weapon it can. It is sometimes stated that this opportunist policy will cost more than the specialised policy; but this does not follow at all. Ultimately we have to frame our measures according to local feasibility.
FIRST STEPS

40 Conduct of the Campaign.—Up to the present most of the anti-malaria campaigns have been due to the intelligence and energy of individuals, but it must be the desire of all and certainly this book has been written in the hope of it—that similar work should now be attempted in every civilized malarious country. This has not hitherto been done, because often neither governments nor health departments have known how to commence and to organise their efforts. I propose now to make some suggestions on the point. They are based upon the scheme proposed by me for Mauritius, after careful consultation with the capable medical profession of that island. They are tentative suggestions, and alterations of detail may be required under other conditions, and even in Mauritius, but I hope that, with such alterations, the general scheme will prove applicable to most malarious countries, especially in the tropics.

First step.—Whether the campaign is to be a large one or a small one, the authorities must begin by educating, not the public, but themselves regarding the simple but often ignored axioms of section 38. The following points must also be remembered:

1. In most places the campaign can never cease—the disease can seldom be extinguished once and for ever, until civilization has reached a much higher state. Much should be prepared for the fact that malaria reduction must become a permanent part of the general sanitary campaign.

2. Unless the work is to be a pretence it cannot be attempted without expense. Perhaps the ideals of the third and fourth axioms cannot be reached—but they must be remembered. Rarely can we destroy as reducible an enemy without some expenditure. But every penny spent is likely to save pounds both to Government and to the public. Moreover, though the war may never cease, the cost of it is
likely to diminish with good administration, and especially with success.

(c) Public instruction must always be given, but, except perhaps in very civilised states, it is not likely to be entirely effective by itself. The individual may take quinine, use nets, or prevent breeding in his premises, but he cannot force his neighbours to do so nor can he clear the surrounding country or drain the marshes. Only the better educated classes are likely to attend to sanitary advice. The great public is an infant for which everything must be done by the nurse. The poor are too poor, the idle too idle, the busy too busy, to concern themselves much with sanitary injunctions. Nevertheless, instruction costs the state little and may occasionally reach the small percentage of the wise.

(d) Sanitation is a form of war. It requires not only money and effort, but also thought, organisation and discipline.

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Appointment of a director. — This being the case the first thing to do is to appoint a commandant. For a small campaign in a town or district, the proposer of it, whether he be an administrative, sanitary or medical officer, had better appoint himself (without salary) and then proceed to collect what army he can in the form of sanitary inspectors, medical assistants and even policemen. He can then begin to ask for funds. But this is personal effort, and for larger areas Government should appoint a special officer in the Sanitary Department. His pay and status must depend upon the area to be dealt with. He should be thoroughly acquainted with the subject and also with general sanitary administration—a medical man, or possibly an entomologist or engineer, or for very large areas an administrative officer.

For entire countries I advocate the construction at once of a Malaria Bureau as part of the general Sanitary Department—
that is, a director with a trained "malarialogist," an entomologist,
a sanitary engineer, and a statistician as subordinates, and a
suitable office. The bureau will collect information and co­
ordinate efforts throughout the country, will carry out inspec­
tions, give advice, examine results, and publish reports.

Those who have no acquaintance with public affairs may
think that this is an extravagant suggestion. In 1914 I mooted
the idea for India through the Secretary of State. In that
country malaria has been officially estimated to cause about
1,000,000 deaths annually. Government spends enormous sums
on plague, which has a smaller mortality and much smaller
morbidity; but a mere drop on malaria. My suggestion was
not accepted, and not even a director was appointed. Hence
the efforts made there have been, in my opinion, too discon­
tinuous for success (section 51), and much of the money spent
has possibly been wasted.

The head of the Sanitary Department must often himself
direct the anti-malaria work. He will do well to begin at once
by collecting a permanent special staff. This will cost money;
but it will save much more which is otherwise likely to be
wasted on inexperienced efforts. Public work is permanently
successful only if directed by officials who are permanently
interested in its success. Local enthusiasts perform great
services in originating campaigns, but they alone cannot
maintain them for ever.

General anti-malaria work is now sure to be commenced in
most civilized countries, and it is high time that governments
should prepare for this by providing the necessary adminis­
tive nucleus.

1. Anti-malaria Leagues, under the presidency of high
officials, consisting of numbers of medical men and influential
persons, with a central office and local branches, should be
started at once—have been, in fact, already started in many
places. They serve to interest the public, to disarm opposition,
and to enlist active allies. To them should be entrusted the
dissemination of information regarding the disease by the well-known methods of placards, pamphlets, posters and lectures.

Personally, I think it wise not to demand a general subscription for membership, as this tends to limit the list, but to ask for donations from Government and wealthy individuals in order to pay for the printing and other small expenses of the League. Unfortunately, there is a distinct danger that the Government, as soon as the League has been formed, will attempt to shift responsibility on to it. It is not often that the League will be able to do the whole work. Its duty lies principally in arousing public attention as regards preventive measures and quinine distribution. It can seldom undertake extensive mosquito eradication or much opinion distribution. Lastly, as soon as the weary minds off, the efforts of the League may tend to slacken.

1. Legislation.—The next thing required is to reconsider the local Government and municipal sanitary regulations in order to take power to deal with mosquitoes and other insects. This is largely a lawyer's matter, as most regulations are so framed that they may be interpreted in various ways. The Government will do well, therefore, to call together a committee to consider the subject thoroughly. Certain clauses are given as examples in section 64. It is easy to overrate the importance of legislation in the campaign. The experienced health officer depends upon it as little as possible; but it is, nevertheless, occasionally useful to control objectionable and foolish people. Thus, in Egypt my brothers found it better to ignore such persons rather than waste time over compulsion, and my experience has always been the same. The trouble and expense of bringing recalcitrants to book is greater than what is incurred in doing the work by departmental agency. The wise health officer seeks to trouble the public as little as possible and the amateur one as much as possible. Laws protecting indentured coolies should be carefully revised in the same sense, though this is seldom necessary. All this costs nothing, but requires considerable time to effect in consequence of the unavoidable and
often unnecessary discussion which arise. I apprehend that these discussions will now become shorter because every action is adapting the required legislation. See especially K. Boyle's book (1-40) and sections 30 and 31.

A serious difficulty in the way of all sanitary improvement lies in the inadequacy of punishment often given by legislators for sanitary contraventions. These are too small to be deterrent. Fines, penalties are allowed, and the scale of the penalties, which should be spent on useful work, is not up to the attending events and writing my cases—a complete waste of police funds. This is not freedom but bondage. It is a very poor form of civilisation, in which individuals are allowed to dispose the freedom which civilization has given them by poisoning or injuring their neighbours. If those who make such condigns the laws are called upon to sell by the side of selling poison, as medical men have often tried to find who the victims of the perpetrators of that. They are not that we allow these things to happen in any to petty safeguards. The author of the work, but we have been already due to the stringent discipline exercised; and the police themselves have become thankful for it. Sanitary discipline is like that of the cleanliness against which only the most foolish public relations: his own cost. I would therefore strongly advise the Government which determines upon a general war against malaria. Add to the resist in this matter.

2. The preliminary material forces:—The insecurity for repeated measurements of malaria is quite obvious. With all the time we cannot make any estimate of the expenses which might theoretically be incurred for prevention by area, and 4, and to determine the exact effect of the measures which are taken. Thus, the authorities will not feel the necessity for the demands made on them, nor the value of the work done, and the whole campaign may tend to collapse. This happened in 1909 in Sierra Leone, where the authorities disliked a malaria survey because they feared that it would alarm the public.
Hence, while the League is being formed, the Director will do well to spend some months in making his preliminary measurements according to the principles given in sections 31 and 32. Maps being obtained, the local total death-rates for as many years as possible should be carefully scrutinised and compared with the attendances for malaria at hospitals and dispensaries—the results being entered in the maps and registers. This will cost nothing, but will yield information regarding both local distribution and general prevalence, which will be invaluable for testing the success of future measures.

At the same time the measures proposed in next sub-section to be adopted in schools, including registration of enlarged spleen, should be commenced.

It is now also advisable to make, if possible, a general "spleen census." That this can be done on a large scale at little expense has been proved in Mauritius and Ceylon, where 35,002 and 92,258 children respectively were examined (section 32). Of course, the work cannot be done entirely by the Director himself. Orders should be issued to Government medical officers to undertake it each for his own district, and the help of all medical men, of trustworthy assistants and dispensers, and of large employers of labour should be solicited. Travelling expenses must occasionally be paid, and I think that fees ought to be allowed under certain circumstances; as the gratuitous services of medical men are too often demanded as it is. The Director should set the example by examining as many children as possible, and he must, of course, register all the results.

The season during which the spleen census is taken is important. In the middle of the malaria season the figures are probably very variable; so that it would be better to select a time before or after that season. I advise between one and two months before the commencement of the season, or a period within about one month after the end of it—in the hope of obtaining the minimum and maximum spleen indices.
respectively. In fact, for the first year I advise that the census be taken twice, namely, at the periods mentioned. Of course, it is not necessary or possible that all the children should be examined on the same day, but I think that the work ought to be done within about one month.

(b) Measures in schools.—From this point the actual campaign commences, and the first principle requiring attention is that the cheapest measures should first be set in train. The Director will be able to do much at little cost with various public institutions, according to the principles laid down in section 17. Schools, if they exist, furnish an admirable opportunity for large-scale work. In most countries the schools are either maintained entirely by Government or are given what are called "grants in aid," or at least licences. This enables Government to maintain a close control over the health of the children, and the Director to use the schools for his great purpose. Two uses can be made of them: 

1. by the treatment of children with fever or enlarged spleen, and 2. for the repeated measurement of malaria. Both measures are especially suitable for children since they are the principal homes of the parasites. I advise as follows—

1. That every school be visited once a quarter by a suitable medical officer (who may, if necessary, be paid for the work).

2. That at this examination the medical officer shall select all children with enlarged spleen, or with fever at the time of his visit, and shall enter their names in a register kept by the schoolmaster.

3. That at the same time the medical officer shall advise the schoolmaster as to the treatment to be given to the child during the next three months.

4. After the inspection the medical officer should report to the Malaria Director the number of children found to show signs of malaria, and the latter should incorporate the facts in his statistics.
At the next inspection the medical officer should observe the number of newly-infected children and those who have become cured, and should again report the facts to the Malaria Director.

The schoolmaster should give the medicine to the children as ordered by the medical inspector.

Quinine may also be advised for the children who are not suffering from fever or enlargement of the spleen, but no compulsion should be used to force them to take it.

The Medical Department should supply quinine in freshly-made pills or tablets, in appropriate doses, to each school. This may be done gratuitously for the schools of the poor, but I think that payment should be demanded in some cases. Different doses should be put up in different canisters, and sweets may be allured for small children.

The medical inspector may stop the drug, if in his opinion it disagrees with a child.

I do not advise here as to the amount of the drug, which I think had better be left to the medical officer. A useful plan is for the schoolmaster to give the medicine when the child first comes to school in the morning. It may not be considered advisable to dose the children every day during the whole three months, though this may perhaps be done at certain times. Perhaps the first fortnight of each month ought to suffice, at least for a trial. During the malaria season the drug may be given more continuously, and during the non-malarious season, less so.

3. Estates or estates, factories, etc.—There are generally large numbers of children in connection with the above, and these may be managed in exactly the same manner as children in schools. Estates often have their own medical officers, who should be directed to keep the registers, to give the quinine, and to report every quarter to the Malaria Director. The
latter will thus possess an excellent standing record of the state of health upon each estate or factory.

In addition to the adults on estate and factories must also be continuously treated if they are sick. The defect has generally been that they are given doses only for a day or two, thus accentuating their frequent presence at the dispensary, a thing which causes endless trouble both to dispensaries and to patients. It is much better to give sufficient quinine to last for a week, or fortnight, or more, according to section 36.

Whether quinine should be used for prophylactic purposes depends upon the severity of the local endemicity, the possibility of reducing Anopheles, and the judgment of the Director seen especially section 37.

Whether quinine is to be supplied gratis to plants, etc., depends upon the local labour regulations.

b. Other quinine distribution.—I suggest the following steps in accordance with section 36:—

1. A number of quinine dispensers, who are duly qualified dispensers, should be appointed under the Malabar Director.

2. Each dispenser should be stationed at a convenient centre within an area allotted to him, and should spend the whole of his time in house-to-house distribution of quinine to those who he thinks require it.

3. He should be provided with a small portable case, to be carried by himself containing a day's supply of quinine in the form of pills or tablets, put up in canisters, of different doses.

4. He should be provided with a uniform, or at least an official badge, and a written authority stating his duties.

5. Every day he should visit a number of houses allotted to him.

6. On coming to a house he should offer the quinine
grants to all persons who suffer from fever or enlargement of the spleen. He must not demand nor take any payment whatever, either for medicine or for his advice.

(2) He may give the drug to any person who demands it, in doses sufficient for a week or a fortnight, if he thinks that that person is infected or is in imminent danger of becoming infected.

(3) He may also examine children for enlargement of the spleen, if permitted to do so by the occupants of the houses, and shall keep a record of the number in which he finds the symptom.

The quinine dispensers should be well instructed in their duties, and in a knowledge of malaria in general. They should furnish a report every month to the Malaria Director.

The Malaria Director will be well advised to send these men most frequently to the most intensely-infected areas, and utilise them also, if necessary, for providing verminicides and sulphur ointment to the very poor. The cost of this will be but small and the advantage great.

In addition to the quinine dispensers, I advised in my report [407] that a change should be made in regards the distributing of quinine to out-door patients of hospitals and dispensaries. It is quite insufficient to give patients only a few doses for a few days. Enough should be given for a fortnight or more.

In Mauritius we found that one dispenser could visit 200 houses a week, and give away about 2½lbs. (about 1,200 grammes) of quinine to about 60 sick, or nearly 3 grammes to each.

I must again remark that to be really useful the drug must simply be poured out in unlimited quantities. A certain amount may be sold, but stinginess in this particular tends merely to defeat the main object in view. Government quinine may
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be distinguished by a certain colour, as done in India; authorities should guard against the possibility of their misuse being subsequently resorted to by persons or firms, etc. But too many precautions will have the effect of nullifying the whole scheme, the object of which is wide distribution, for the sake of saving a few pounds. The cost of collecting money for small sales, and of sending in reports of exact amounts distributed, really exceeds the cost of wages, under which this is allowed entirely without any limit. Government must, therefore, face a certain loss from leakage, but this should be looked upon as an unavoidable part of the general cost of the campaign.

Moustiquiers—We now turn to mosquito reduction. The first necessity, an absolute one, is for the Director to have a number of subordinates well trained in a knowledge of mosquitoes. In Marseilles we called these ‘mustiquiers.’ They were paid about 25 rupees a month, and were mostly of Indian extraction. The men should be carefully selected for intelligence and reliability by the Director himself, and should be trained into a class to be trained by him personally. It will be found that they learn their work in a surprisingly short time, and generally take great interest in it. Each man should be taught how to catch adult mosquitoes, and how to find larvae in all possible breeding places; also how to fill up holes in tree and rocks, and to direct the range of workmen required for clearing pools and streams, etc. The appointment should be made with a view to permanency, with a scale of increasing salaries, and, if possible, with a promise of pension. This is obviously an economical principle, because after a year or so the mustiquiers become highly experienced in their work. After he is trained, each man should be allotted a given district, consisting, either of town or of village, or of open country, according to the judgment of the Director. The duties of the mustiquiers will consist in ascertaining all the breeding places in his district, in guiding the works of the malaria gangs, and in making occasional
reports to the Director. Oral reports generally suffice. It may
be advisable to appoint head mosquitoes to superintend larger
areas. Each investigator should be provided with a white
enamelled pan or vire for finding larvae in water.

These men are essential for a continued campaign against
mosquitoes. They are, so to speak, the local eyes of the Director.
Without them there will be no permanence in the measures,
because directors and superintending medical officers may
change from time to time, while the staff of mosquitoes will
be permanent. In fact, many campaigns have failed because
this fundamental point was overlooked.

The number of mosquitoes will depend upon the amount
of work allotted to each. I suggest that one man can super-
intend quite a square mile of area, except in crowded towns.
If the campaign is to include Culicine reduction, more men
will be required for towns.

Mosquitoes are exposed to considerable risk of infection.
Care must be taken of their health, and they must be provided
with bed-nets.

The Director can send his most reliable men to outlying
stations and plantations in order to report to him as to mosquito
breeding there, and also in order to instruct managers, head-
men of villages, and so on, a thing which he cannot always
do himself.

11. Malaria gastro for minor works.—The mosquitoes do
not do manual labour, which is entrusted to workmen of the
class usually employed for gardening and engineering works.
The duty of these workmen should be to train small pools,
to keep street gutters, surface drains, roadside ditches and
channels, margins of ponds and streams clear of weeds and
obstructions; to carry out rough canalisation of streams, to
delep or “back-up” breeding-ponds; to fill or other waters;
to fill holes in rocks and holes in trees; to cut under-
growth; and to deal with house waters which breed Culicines
From our experience in Mauritius I advised that the work
men be formed into gangs of about three or four men each.
One of the men should be appointed the headman of each
gang, with extra pay, and should be responsible for the work
of the gang. This extra pay is an inducement for the work
men to remain in such employment, which, like that of
mosquitoes, requires considerable training for economical
working; and it is astonishing how much trained men will
do in a given time.

It is impossible to state how many gangs will be required
for a given area. This will depend entirely upon the local
conditions. In Mauritius I thought that one gang could
manage about a square mile at a very rough average, and
the cost of each gang was about 15(3) rupees a month.
The gangs are to be superintended by the medical officer,
by special headmen if necessary; but the Director must
frequently examine the work done. It may also be frequenily
feasible to put the gangs under enthusiastic local medical
officers, or district officers, or members of the Anti-malaria
League, subject, of course, to the final authority of the
Director.

Local offices. — All this organisation — dispensers,
mosquitoes and malaria gangs — will require a number of
local offices where the men can be given instructions, paid,
supplied with medicines, oil, tools and implements, etc.
Generally, as the whole organisation is under the Medical
Department, it will be better to make local dispensaries the headquarters of
each local malaria administration; but, of course, this question
depends upon conditions. I do not think it is necessary to
appoint a special clerk at each dispensary. Perhaps the sanitary
inspector's office may be more convenient than the dispensary
in many cases.

Major works. — Here the fundamental principle of
paragraph 31 (b), namely, that of minor works before major works, must
always be remembered. It is folly to commit the state to a
large expenditure where a small one may suffice. At the same
time it may sometimes be more economical to do the major
work at once. Hence, at an early stage of the campaign, the
Director should obtain rough conjectural estimates of the cost
of all major works that may be required. Exact estimates
can only be obtained from the Public Works' Department at
considerable cost, incurred for accurate surveying and skilled
advice; but Government will generally be able to ask its
engineers to prepare the rough estimates by mere inspection
of the localities concerned. These rough estimates are now
borne in mind by the Malaria Director, who shapes his policy
accordingly.

Of course, major works will generally demand not only a
considerable capital outlay, but also an annual expenditure
for maintenance. Government always finds a considerable
difficulty in obtaining the former item, which may require loans
and the consent of higher authorities. The Director should,
therefore, generally not make such demands, until he is con-
vinced by the unsuccessful result of minor works during several
years that the expenditure is absolutely necessary; unless he
and the Public Works' Department consider that money will
thereby be saved in the end.

The important question as to who is to pay for drainage
of marshes on private property often arises, and I was asked
in Mauritius to advise upon the point. I first enquired officially
whether owners could be forced by law to drain such marshes,
or to pay for the drainage of them by Government, especially
in view of the fact that such drainage might greatly enhance
the value of their property. In reply I was informed that in
the opinion of the Law Officer, marshes could not be held
to be nuisances in the statutory sense of the word; and that
legislation had been proposed but prevented many difficulties.
The answer seems to me to depend upon (a) whether the
existence of the marsh is or is not the fault of the owner,
and (b) whether the removal of it would or would not benefit
the general public as well as himself. For instance, it there
is in existence a sufficient and practical outfall for the marsh,
or other means of dealing with it in the owner's property, but
not which the owner neglects to use or refuses for his own
profit to use; and if he neglects to render the marsh innocuous
by such reasonable minor works as may be required by the
Medical Department; and if it is proved that the marsh is
actually causing sickness, or, in the opinion of the Medical
Department, is likely to cause sickness, then I think that
he (the owner) may be forced to do the work. As a matter
of fact a marsh in a malarious country is a nuisance, and the
fact that it is not recognized by law proves only the truth, and
of the latter. If a person can be forced to remove or clean
a latrine, he ought most certainly be forced to remove or
discharge a marsh, and for the same reason.
On the other hand, if the owner of a marsh has done all
reasonable minor works to render it innocuous; if the major
work is beyond his means, or cannot be carried out on his
property; and if the marsh is not causing, or is not immedi-
ately likely to cause public sickness, then I doubt whether
he can fairly be forced to undertake the expense. Each case
must be judged on its merits; and Government will often feel
it more fair to pay at least a part of the expense. At the
same time, legislation to compel defaulting owners should
certainly be passed.
Precisely similar difficulties often occur in connection with
water-ways, drains, polluted streams, and especially irrigation
channels; and I think they may generally be met on the
same principle.
(13) The annual malaria report.—I think it is most essential
that a report upon the work done should be submitted to
Government every year. It should be prepared by the Malaria
Director, and should commence with a detailed statement of
the measurement of malaria for previous years as well as for
the year under review. It should then describe the measure.
taken, the number of men employed, and the cost; and should conclude with remarks upon the results obtained.

This report will enable Government to judge whether or not value is being received for the money spent. Officials are apt to dislike the trouble incurred, but it is a necessary one. In British possessions, one often finds a single perfunctory annual report on medical matters, and we should compare such with those excellent monthly reports issued by the Americans for the Panama Canal Zone.

(141. cont.) I will content myself by giving the approximate estimate which I prepared for Mauritius (1908):

<table>
<thead>
<tr>
<th>Item</th>
<th>Rs. per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Salary of the Malaria Authority</td>
<td>6,120</td>
</tr>
<tr>
<td>2. Salaries of native Proprietors (say)</td>
<td>6,000</td>
</tr>
<tr>
<td>3. Salaries of native Subordinates</td>
<td>4,100</td>
</tr>
<tr>
<td>4. Salaries of native Organisers (say)</td>
<td>1,000</td>
</tr>
<tr>
<td>5. Cost of supplies (say)</td>
<td>1,500</td>
</tr>
<tr>
<td>6. Preparation and dispatch of quinine (say)</td>
<td>5,000</td>
</tr>
<tr>
<td>7. Office of Malaria Authority (say)</td>
<td>1,500</td>
</tr>
<tr>
<td>8. Travelling expenses for staff (say)</td>
<td>5,120</td>
</tr>
<tr>
<td>9. Medicine for possible calls</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Total

This amounts to £5,000 per annum for a population of 373,400 (1900) or 0.13 rupees per head per annum, or 1/7 of the total revenue.

The estimate was an "outside one." The number of gangs of men was determined, not by myself, but by the Medical Department, and many suppose that it is considerably in excess of the actual requirements. In fact, I have since heard that the whole work can probably be done at much less cost. My whole scheme has, however, been held over pending the final settlement of the financial position of the Colony. This has only just been effected (1910), and I hear that the scheme will now be proceeded with.

In addition to the above annual expenditure, we had to
consider the major works. A rough conjectural estimate for these was prepared by the Public Works Department and was put at 630,000 rupees for capital expenditure, together with 42,500 rupees for annual maintenance. But, as I have said, I hope that experience will prove that little of this will really be called up.

Critics of my report have complained that such expenditure, though it may be possible for Mauritius, will be altogether too vast for other countries. The total revenue of Mauritius is 9,918,869 rupees, of which 740,827 rupees was allotted to the Medical and Health Department and to quarantine. Hence the proposed [malaria] expenditure amounted only to 1/2 of the total revenue, and to 1/10 of the medical and sanitary revenue, while the disease causes 1/3 of the total sickness, and costs the colony about 7,000,000 rupees a year (section 372). The sum of about one-third of a rupee per head of population is scarcely too much to pay for all the advantages, not only of malaria reduction, but of very considerable mosquito reduction, and general "cleaning up."

Moreover, I may once again that the malaria gangs can be largely utilized for general sanitary purposes, and for performing many useful offices during the non-malarial season. On the whole I am quite convinced that this expenditure would be a very small one for any population, compared with the benefits obtained.

Of course, the Malaria Director will have to prepare similar estimates before he engages large numbers of men. Unfortunately, it is always impossible to state without trial how many gangs are required for a given area. Thus, the Director is almost forced to commence with the most populous areas and especially with the most malarious ones. He must point out these difficulties to the Government and must do the best he can.

(13) Remarks. — Amateurs are fond of advising that all practical measures should be postponed pending the carrying
out of detailed researches upon the habits of the Anophelines, the parasite rate of localities, the effect of minor works, and so on. In my opinion this is a fundamental mistake. It implies the sacrifice of life and health on a large scale, while researches which may have little real value, and which may be continued indefinitely are being attempted. As a matter of fact, the campaigns at Havana, Panama, Jamaica, and the Federated Malay States, were all commenced before the local carriers were definitely incriminated and their habits studied. We already know the broad general principles that these carrier breed in more or less stagnant waters, and that protection and prevention by treatment are valuable. More exact knowledge of the habits of the carriers is certainly often very valuable, because it enables us to deal more economically with them; but, if the principle of minor works before major works is remembered, we need not wait for the full development of such studies. Moreover, the Medical Director will be able to carry out such researches much more effectively by the aid of his medical officers and quinine dispensers than by himself in a long preliminary survey during which the people are allowed to continue dying. In practical life we observe that the best practical discoveries are obtained during the execution of practical work, and that long academic discussions are apt to lead to nothing but academic profit. Action and investigation together do more than either of these alone.

I strongly advocate a generalised campaign in preference to one which deals only with a few spots. The former is likely to be more economical in the end and the latter is more likely to dishearten the authorities and to waste money. At the same time financial considerations will almost always demand stronger efforts in the larger, more populous, and most malarious localities—at least to begin with. But the Director must always hold in mind and prepare for extension to every part of his domain.

In conclusion, I believe that anti-malaria work can be
effected for little cost in all malarious countries, and will soon be attempted everywhere. The success of it depends, not so much on produse expenditure, as on the intelligence, enthusiasm and energy of those who are responsible for sanitary affairs. He who undertakes the work must remember that he is a soldier in one of the greatest of crusades, which has for its object the conquest of the tropics for humanity.
CHAPTER VII

SPECIAL CONTRIBUTIONS

By Professor L. G. Howard
Chief of the Bureau of Entomology, Department of Agriculture,
Washington, D.C., United States

41. Anti-malaria Work in the United States. — Beginning

with 1900 and gradually increasing in amount year by year,
a great deal of anti-mosquito work, more or less well planned,
has been done in different parts of the United States; but,
looking over the entire field, it is astonishing to note how little
of this work has been done with a direct sanitary object in
view. The sanitary point has been held constantly in mind
in the operations conducted under the United States Govern­
ment in Cuba, on the Isthmus of Panama, in Porto Rico, and
in the Philippines, but in the United States, while malaria is
prevalent in large regions, such work as has been done has
been instituted for the most part with the sole idea of relieving
localities from the nuisance of mosquitoes, thus not only render­
ing living conditions more agreeable, but increasing the value
of real estate. In fact, one of the best bits of work done was
accomplished by means of a large sum of money presented
by a wealthy man whose object was not primarily the improved
health of the people of the region, but bettering the condition
of his high-priced race-horses, which were suffering from the
abundance of mosquitoes. Nevertheless, what anti-mosquito
work has been done naturally has resulted in improved con­
ditions in health in localities included within the scope of
operations.

A great deal of valuable drainage work has been done
in the past few years in the salt marsh region of the North
Atlantic coast, and there is one instance of this upon the Pacific coast, with the direct idea of doing away with the salt marsh mosquito, several species of which occur in such localities, all having unusual power of flight, and being able to proceed inland for many miles, thus annoying the inhabitants of a large extent of country. In America Aedes aegypti mosquitoes are rarely found in salt marshes, and, in fact, there is but one record of the finding of Aedes larvae in such localities in the United States.

One of the first operations of this kind was conducted by the wealthy owners of Center Island, off the north coast of Long Island in Long Island Sound. This led to some elaboration work under the organization known as the North Shore Improvement Association, which included simple operations over a considerable distance along the north shore of Long Island, and in the vicinity of Cutchogue Bay. In the course of this work the breeding places of Aedes were studied and mapped, and especial effort was made to destroy them. These operations took place in 1902 and 1903, and have been reported at length in a small volume published by the Association. Later some excellent work was done at Lawrence, Long Island, which demonstrated the feasibility of controlling the salt marsh mosquitoes by relatively simple and comparatively inexpensive ditching operations. These operations were continued for four years at an annual expense of something more than one thousand dollars per year.

The work in the early part of the short period of years was usually started here and there by intelligent and up-to-date citizens, citizens' associations, city improvement societies, and women's clubs. The California work, taken up in 1902, was done under the auspices of the Burlingame Improvement Club. Excellent anti-mosquito work was begun as early as 1900 on Staten Island, New York, by the Richmond County Club. Admirable community work was taken up during 1901 and 1902 by certain New Jersey towns, notably South Orange.
Elizabeth, Montclair, Monmouth Beach and Summit, and a little later independent work was begun in Greater New York under Dr. Eberle, which included the mapping of all mosquito breeding-places within the city limits. Independently, the health officers of Brooklyn, Jamaica and the Bronx began efficient work, while the summer resorts of Avenue and Woodmere reduced the mosquito supply by intelligent operations.

At Willets Point, New York, intelligent and efficient work was carried on on a small scale. In Massachusetts interesting and important work was done at Brooklyn and at Worcester.

In Brooklyn the Board of Health first considered the work in August 1901, and in September all the breeding-places of Anopheles and other mosquitoes were treated. In 1902 all pools, ponds, ditches and other breeding-places, including catch-basins, were located on the town map, the approximate areas were determined, and the number of catch basins ascertained; breeding-places of Culex and Anopheles respectively were determined, and also places where both species were breeding together—this being done in order to ascertain the proper intervals for treatment—that is, whether every two weeks or every three weeks. Public dumps and other places where accidental receptacles of water might be found were located on the maps. Light fuel oil was used on all breeding-places.

At Worcester the work was of the most interesting kind. Dr. William McKibben and Dr. C. F. Hodge started the crusade. Breeding-places were mapped and photographed, and public lectures were given. The school children of the several grades were interested, and were organized into searching parties. Many breeding-places were filled up, and others were treated with kerosene. The prevalence of malaria in Worcester was pointed out by those engaged in the crusade, and the relation between mosquito breeding-places and the houses where malaria patients lived was shown. A map was prepared showing the exact distribution of malaria in the city, and photographs...
were made showing the character of the breeding-places of the malarial mosquitoes. It is probable that these were
the first made in this direction, although the idea was carried out to a much greater extent later in San Antonio, Texas, by Dr. J. N. Laidlaw.

Other early work was carried on at Pine Orchard and Ansonia, Connecticut, and Old Orchard Beach in Maine, and on the campus of the Michigan Agricultural College in Michigan. At Atlanta, Georgia, the Sanitary Department used a large amount of kerosene in the stagnant pools and the swampland around the city, and warned the citizens to sink their rain barrels and to keep their gutters open. A great many pools of water were drained. In Savannah some work was done, and the number of mosquitoes was reduced very considerably. At Fallasburg, Michigan, under the direction of Dr. R. R. Simms, anti-mosquito work was commenced early in 1907, and carried out systematically. St. Louis took up the work early in 1907, and the Municipal Assembly made an appropriation for supplies. The Health Department, however, was hampered for lack of men and little work was done.

Many of these and other efforts were spasmodic and only temporary in their effect; even the boards of health in some instances lost interest. An excellent example of the difficulties encountered by intelligent citizens was shown in the city of Baltimore. Intelligent individuals pointed out very early that a large part of the mosquito supply of the city could be easily handled, and year after year, in public press and before the Board of Health and the City Council, these persons continually agitated the subject of anti-mosquito and anti-malarial work. Finally, in 1907, Mr. George Stewart Brown, a member of the City Council, succeeded in getting an appropriation to start the work for that year. Much of this money was expended in extensive advertising in the street cars, etc., but the remainder was expended very efficiently, though necessarily
with only partial results, by organizing a gang of men to drain and fill up the pools in the vacant lots around the suburbs. Next year the appropriation was reduced, and only this gang of men was continued. During 1909 no appropriation was made, the gang of men was dropped, and the whole question was abandoned. It should be stated, however, that before the appropriation was made an ordinance was passed by the City Council requiring every household to remove, screen with wire-netting, or keep covered with oil all standing water around his premises, but it seems that no real attempt was ever made to enforce this ordinance. Of course such an attempt could hardly be successful at first without the aid of an especial appropriation for the purpose, and at the present time the ordinance seems to be a dead letter.

It is pleasing, in the face of so much of this sort of thing, to note a well-directed and rather large-scale bit of work with a direct anti-malarial bearing, which was begun at an early date, and that is the work on Staten Island under Dr. A. H. Doty, the health officer of the port of New York.

Staten Island, lying in New York Harbour, had had a rather enviable reputation on account of the great number of mosquitoes present and the continued presence of malaria. It was largely on account of the latter condition that Dr. Doty began his investigation in 1907. He soon found that there were two factors to deal with in this work, namely, the inland mosquito and the salt marsh mosquito.

In the extermination of the inland mosquito, the section of Staten Island which was known to contain many cases of malaria both in the acute and chronic forms was selected for experimental work. This section consisted of a basin or lowland about a mile square, containing about one hundred small dwelling-houses some distance apart. Within its boundaries were a large number of stagnant pools varying in size from ten feet in diameter to an acre or more in area. A house-to-house visit showed that at least 20% of the inhabitants of this
district were suffering with some form of malaria, and in the
immediate vicinity of every house were found typical breeding-
places in the shape of old tinware, rain-water barrels, cisterns,
mosquito and ground depressions, many of which contained
larvae. For the purpose of detecting the presence of adult
Anophelus, glass tubes fitted with cotton plugs were distributed
among the occupants of these houses with the request that the
mosquitoes found in the house at night be captured and placed
in the tubes. In the collection were found many Anophelus.
These were particularly numerous in tubes cutting from a small
group of houses. In one of the latter was found a family con-
sisting of five persons, all of whom showed the acute or chronic
form of malaria. Dr Doty himself secured live mosquitoes from
the interior of this house. On the first evening five were
captured, and all but one were Anophelus. On the second
evening twenty-two were collected, and of these more than one
half were Anophelus. In the house on the opposite corner was
found a patient suffering from an acute attack.

In the beginning considerable difficulty was found in detect-
ing the breeding-places of the Anophelus, but this became
easier as the inspections became more thorough. For instance,
in a group of two or three houses close together a number of
Anophelus were captured, but their breeding place could not
be found for some time. Finally, in the backyard of one of
the houses, overgrown with weeds, was discovered a very large
metal receptacle filled with Anophelus larvae, and with many
adults in the immediate vicinity. This receptacle was almost
entirely covered by underbrush.

After this experience the men employed learned to make
the closest possible search, and to find probably every breeding-
place.

The island was then divided into small districts, which
were visited by mosquito corps consisting of five men, one of
whom was a sanitary police officer connected with the New York
City Department of Health. The equipment of the mosquito
corps consisted of a large wagon provided with spades, rakes, hoes, scythes, and petroleum oil. A house-to-house inspection was made in each district. House owners or tenants were required to remove from about the premises all receptacles which might act as breeding-places, or to protect them. Rain-water basins and cisterns were covered with wire-netting; all roof gutters were repaired, and pools of water were covered with petroleum. In certain instances orders were sent to the owners of property containing depressions in the soil to fill them in or drain them. If these orders could not be enforced, the mosquito corps returned every ten days or two weeks and applied more petroleum. Copies of a circular of information were delivered as far as possible to each house on Staten Island by police officers, and the educational campaign brought about valuable cooperation on the part of the public.

In 1905 the details of this work were presented to the Department of Health of the city of New York, and the city government granted an appropriation for the drainage of the swamp land along the entire coast of the island. With the aid of this appropriation, ditching was carried on throughout in the same manner in which it has been carried on in New Jersey. Down to the present time between 500 and 1,000 miles of ditches have been dug. The swarms of mosquitoes have practically disappeared, window screens were discovered, and meals were served upon the verandas of the hotels.

With the malarial and other inland mosquitoes the work was carried on in the manner above described, not only in the built-up portion of the Island, but also in the open spaces between the small and scattered settlements. During the past two years cases of malaria on Staten Island are becoming practically unknown, and for the past year Dr Doty has been unable to secure any Anophelus, whereas, in the beginning of the investigation they were found almost everywhere on the island. The statistics of the Department of Health indicate the decrease of malaria from 1903 on. Prior to 1905 malaria
RESULTS OF DR. DOTY'S WORK

was not regularly reported, but the number of cases was very much greater than that reported in that year. Since 1893, however, they are stated to be as follows: 1893, thirty-three cases; 1894, fifty-four cases; 1895, four cases, and six cases; from five cases.

The work of exterminating medicinal mosquitoes has been carried on slowly in the area involved. Considerable the island being about 66 miles long and 2 to 6 miles wide, probably containing over eighty thousand inhabitants at the census.

The expense of the operations done to the present date has been about $400. This, of course, includes the expense of the extensive drainage operations in the salt marshes. In 1893, in addition to being the Health Officer of the Port of New York, is a Commissioner of Health of New York City, and he carried out this work in his capacity as a municipal officer, and not as a State official.

Earlier and very much smaller pieces of work have previously been described by the writer in "Mosquito," New York, 1903, including the work done by Dr. William Berkeley, a small town near New York City during the summer of 1892, and the work done at Chopticks, Maryland, by the Rev. William Brayshaw, in both of these cases the work being directed primarily against mosquitoes. Later some excellent work was instituted through the combined action of the boards of health of Cambridge and Belmont, Massachusetts, to improve the sanitary condition of the cities of Cambridge and Somerville, and the towns of Arlington and Belmont, at the suggestion of Dr. W. L. Underwood, a member of one of the boards of health. This work was effectively carried out at an expense of $500 without assessment upon landholders.

In 1893 some extensive work was done at Newport, Rhode Island, at the expense of a single property holder, and the following year the Citizens' Association of Hasking, Long Island, took up the problem, and with the assistance of the
Board of Health extensive drainage operations have been carried on, but are not yet completed.

In 1903 the American Mosquito Extermination Society was founded, and took an active part in interesting the people of the United States in the mosquito crusade. It was founded for the purpose of educating the public, of bringing about legislation, and of securing cooperation and exchange of ideas. It held its first anti-mosquito convention in December 1903, and continued its organization, publishing several bulletins, finally disbanded in 1907 in consideration of the fact that the object of its existence would be taken over by the National mosquito Association.

In 1903 and 1904 work against mosquitos was undertaken by the state entomologist of Connecticut, Dr. W. E. Britton, who made careful mosquito surveys over the whole state and published in his Annual Report for 1904 a careful and well-illustrated article devoted to showing how the mosquito nuisance can be abated.

The largest-scale work taken up in the United States, however, has been carried on by the State of New Jersey, and this is the first of the United States to take official action in this direction. This work was instituted by Dr. John B. Smith, the state entomologist, and has been carried on, and resulted largely from his discovery of the exact habits of the salt marsh mosquitos. An admirable state law was passed carrying a very considerable appropriation. The law provided for a survey at the request of the board of health of any city, town, or township, which should map all mosquito breeding-places, and provided that the board of health must, after the survey, proceed to abolish the breeding-places. The law provided further that if the necessary cost of the work shall equal or exceed the value of the land without increasing its taxable value the board may apply to the director of the work, who may, if he deems the matter of sufficient public interest, contribute from the state funds to the cost of the necessary
work, providing that not more than 5% of the amount shall be contributed in any one. Under this appropriation and during the past three years much admirable work has been done upon the salt marshes of the New Jersey coast. In all 23,442 acres of marsh land have been reclaimed by 193,787.4 feet of ditching, and this includes a shore line of nearly 75 miles. Other work has been done also, more specifically against salt-marshes, including Apalisina.

The work that was done in New Orleans during the yellow fever outbreak of 1905 was an object lesson to the people of the United States. This work was so thorough that it resulted in the reduction of the numbers of the yellow fever mosquito to a minimum, and at the same time sensibly decreased the numbers of Apalisina. This work, while carried on originally under the United States Public Health and Marine Hospital Service, has been continued by the city Board of Health, and the example of New Orleans in this direction has been slowly followed by other southern cities.

The city of San Antonio, Texas, has the honor of instituting and carrying forward a large-scale effort to educate the children in the public schools, which is worthy of rather specific mention on account of its widespread application.

In November 1905 there were a few cases of yellow fever in San Antonio which caused several deaths, and an inconceivable interruption of commerce that cost hundreds of thousands of dollars. In the effort to allay the panic, the existence of yellow fever was denied not only by persons having business interests in the city, but by many medical men as well. Very many adults not only denied the existence of the fever in the city, but denied the relation between the mosquitoes and the fever. Perhaps the majority of the adults seemed too old to learn; and to the enlightened physicians it appeared that it was impossible to begin education at the wrong end of life.

The Chairman of the Sanitary Committee of the School Board (Dr. J. S. Lankford) grasped the happy idea that if the
children were properly educated, sanitary matters in the future would be much better attended to. He suggested to the Board that it would be valuable to educate all of the school children of the city in prophylaxis and make sanitarians out of them all.

The School Board heartily approved of the proposition, and the campaign was at once begun to educate the children on the subject of Diseases or Disease Carriers. The best recent medical literature on the subject was procured and furnished to the teachers, and a circular letter was sent to them outlining a proposed course and offering a cash prize for the best model lesson on the subject. Teachers became deeply interested in the subject. A crude aquarium was kept in every schoolroom, where the pupils could watch the eggs and wriggling larvae in the process of development; large magnifying glasses were furnished in order that they might study to better advantage. The children were encouraged to make drawings on the blackboard of mosquitoes in all stages of development; lessons were given and compositions were written on the subject. Competitive examinations were held, and groups of boys and girls were sent out with the teachers on searching expeditions to find the breeding-places. Finally, a prize was offered to the school children of the city in the matter of finding and reporting to the Health Office the greatest number of breeding-places found and breeding-places destroyed. Records were kept on the blackboards in the schools for information as to the progress of the competition, and great enthusiasm was stirred up. In addition to these measures, a course of stereopticon lectures was arranged, grouping the pupils in audiences of about one thousand from the high school down, and, in Dr Lankford's words, it was an inspiring sight to watch those audiences of a thousand children, thoughtful, still as death, and staring with wide-open eyes at the wonders revealed by a microscope. It seemed to me that in bringing this great question of preventive medicine before public school children we had hit upon a power for good that could scarcely be over-estimated. The result of
this work, it is pleasing to say, was a decided diminution in the number of mosquitos in San Antonio. There was some opposition among the people, but the movement on the whole was very popular. One result of this work was that while there had previously been from fifty to sixty deaths a year from malarial trouble, the mortality was reduced 75 per cent in the first year after this work was begun, and in the second year it was entirely 

In organizing community work against mosquitos, the school children hereafter must be counted upon as most important factors. Almost every child is a born naturalist, and interest in such things comes to them more readily than anything else outside of the necessities of life. They are quick-witted, wonderfully quick-sighted, and as observers of breeding-places they cannot be approached except by adults of the most especial training. One of the first steps that a community should take is, therefore, the encouragement of the interest of the children in public works.

I fear that it will appear from what precedes that considering the enormous loss existing in the United States through malaria, which has been estimated by the writer at surely not less than $40,000,000 per year (see Bulletin No. 79, Bureau of Entomology, United States Department of Agriculture), nothing like the competent work has been done that should be done, or really that should have been done in the past eight years, within the territorial limits of the United States themselves. While very many sections of the country that were originally extremely malarious have been practically freed from malaria by the drainage of swamp areas undertaken not as a measure of sanitation but in order to add to the supply of arable land, it is nevertheless seen that the conditions of improved civilization have brought about steadily increased opportunities for mosquitos to breed, and this increase in the number of breeding-places and kinds of breeding-places is constantly growing. The introduction of irrigation into many
portion of the western country has resulted in the introduction of malaria, and these operations are going on with a very rapid increment. Moreover, in regions which are not dry and which need no irrigation, the construction of mill-dams, the excavation of sloughs, the building of railroad embankments and many other operations which follow rapidly increasing populations have resulted in the multiplication of Anopheles, and in many instances the introduction of malaria has been followed by its rapid spread through extended regions. On the whole, under such conditions it would not be surprising if malaria were increasing rather than decreasing in the United States, and the mosquito control is bound to become an extremely important matter within the next few years.

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42. Malaria Prevention on the Isthmus of Panama.

By Colonel W. C. GORGAS, United States Army
Chief Surgeon, Office of Panama Canal Commission, Panama

The Panama Canal extends diagonally across the Isthmus of Panama from south-east to north-west, a distance of 42 miles from shore to shore.

Commencing on the South Sea at Panama it runs up the valley of the Río Grande river to Pedro Miguel, then across the divide to Barú, and from there down the valley of the Chagres to Colon. Roughly, about two-thirds of this distance is broken and mountainous, and one-third low and swampy. About one-fourth of the population lives in the lowlands and three-fourths in the highlands.

Before coming to Panama in 1904 the Army Medical Corps had had very little experience in dealing with malaria on a large scale in rural districts. The mosquito work established by the Army medical officers in the city of Panama in 1901 had not only gotten rid of yellow fever but also of malaria. This work has now been going on in Panama for the past eight years, part of the time under Army medical officers, and part of the time under Cuban officers, and is the most successful example of municipal malarial work that I know of.

The following table shows the decrease of malaria under these measures, and at the present time, its practical extinction —

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Mosquito work commenced February of this year, 1909.
Ronald Ross's work at Batavia was the only example at the time that I knew of pertaining to successful anti-malarial work in rural districts.

At Panama our anti-malarial work is principally rural, located for 47 miles along the line of the railroad between Panama and Culebra. The railroad in general follows the line of the canal. In this distance we have a population of about eighty thousand living within half a mile of the railroad, and occupying some thirty villages and camps, and more or less isolated houses scattered between.

In this article I shall describe the sanitary organization as I visited in July 1908.

This strip of 47 miles along the railroad is divided into eighteen districts, each district in charge of an inspector. The inspector's duties consist in the carrying out of the sanitary work of the district, and for this purpose he had at his disposal, on an average, about fifty men. The anti-malarial work consists in the order of its importance, of—

1. Ditching.
2. Brush and grass cutting.
3. Oiling.
4. Use of larvicide.
5. Prophylactic quinine.
6. Screening.

**Ditching**—This is required to drain and do away with all pools within, approximately, 500 yards of all villages, and 100 yards of all individual houses. For this purpose we consider subsoil drainage by far the most effective and economical; second, open concrete ditches; and, third, open ditches.

The porous subsoil pipes give a perfect anti-malarial drainage. Besides doing away with all breeding-places, they enable you to use a horse mow on the ground so drained, and thus much cheapen the cost of subsequent grass cutting.

We use the open concrete ditch in localities where...
subside drainage is not practicable, such as flat places where the fall is not sufficient, and small natural rills where the volume of water is too large for subsidence drainage, etc.

The objection to this style of ditch as compared with the subsidence is that it requires supervision for the purpose of keeping it free. Any obstacle in the ditch will make a small collection of water, which in this warm climate will breed mosquitoes at any time of the year.

Open ditches are only used when the occupancy is going to be temporary, not more than a year. While the first cost is smaller than in either of the other classes of ditches, the ultimate cost is very large. In a locality such as Panama, vegetation grows so rapidly that the ditches have to be cleared out at least once a month, and when clean they will breed larvae unless treated with larvicide.

We pay our inspectors from one hundred and twenty-five dollars per month to one hundred and seventy-five, and thus get, in general, an educated, intelligent class of men. We have attached to the department an inspector of sufficient engineering education to lay out the ditches, but the local inspector is entirely responsible for their execution. In general, it is the character of work such as the farmer does through our country, and any man of ordinary intelligence is capable of carrying it out. But for its anti-malarial success it is important that the man in charge should have a good knowledge of the breeding habits of the species of mosquito in his neighbourhood.

Brush and grass cutting.—The inspector is required to keep the tropical undergrowth cut off within 200 yards of villages and 100 yards of isolated houses. Within this area the grass must be kept less than a foot high. I consider this scarcely less important than drainage. Brush and grass shelter the adult mosquito, and they will reach a habitation from distant breeding-places by short flight, if they have the continuous protection of brush, whereas the Anopholes will not cross a cleared area of 200 yards.
OTHER MEASURES

Oiling.—We use oil where drainage is either impracticable or too costly, such as in the edges of swamps, edges of streams, etc. In a large construction work, such as the temporary piers are constantly being formed. The oil should be of such consistency that it will spread readily, but not so thin that it will evaporate too rapidly. For this purpose we use crude oil thinned with lard.

Larvae.—There are many places, such as the swampy edge of ponds, or of streams, in which the Anopheles larvae have to breed, and where oil will not spread. In such places we use a poison which mixes in the water and which we denominate larvicide. We have done a good deal of experimenting to get an effective and, at the same time, cheap larvicide. Mr Le Prince gives the formula in his paper. We use per year about 4,000 barrels of oil and about 1,000 barrels of larvicide.

Prophylactic quinine.—We consider quinine taken for prophylactic purposes an exceedingly important measure against malaria. Quinine is given gratis to any one applying to any one of our dispensaries. We have at various points along the line 21 dispensaries. It is placed on all hotel and mess tables. But we place most reliance on our quinine dispenser. In each district we have a man attached to the dispensary who is known as the quinine dispenser. He spends the day visiting the various squadrons of negroes at work. He offers everybody in the squad quinine. He gives it to them as they prefer, either in pill or solution. We do not attempt to use compassion in the matter. Last year we used 3,200 pounds of quinine. Two-thirds of this was given to employees. On an average about half of our force gets a prophylactic dose of quinine each day.

Screening.—We insist upon all government buildings being so screened as to keep them mosquito-proof. The details of screening are very important. It should always be under the supervision of a sanitarian who understands these details. As the sanitary work progresses, screening becomes less and less
necessary. In the older stations, such as Ancon or Colón, I doubt if screening is now necessary. The country has been so thoroughly drained that there are very few mosquitoes, though we still insist upon the screening just as carefully as we did when mosquitoes were bad.

Killing mosquitoes or quaring them.—When a locality has been thoroughly treated and the general sanitary work has not had time to effect malaria, or when malaria is bad from other causes, we attempt to kill the infected mosquitoes. As daylight comes on, the Aedes aegypti, when she has had her fill of blood, will not in general leave the building where she has fed, but will seek some dark corner in which to spend the day. Taking advantage of this we have a man go around and kill all the mosquitoes he can find in the building. In this way most of the infected mosquitoes are killed before they become infectious. This method is particularly effective in tents and small buildings.

It is surprising what results can be obtained by this method in properly selected cases.

Cost.—The total cost of sanitation on the Isthmus for the past five years has averaged annually about three dollars and a half per capita for the whole population of the strip. During that time this population has averaged 10,000. As the general result of this expenditure our death rate for the total population on the Zone has fallen from a maximum of 67.77 per thousand in July, 1905, to 21.22 in December, 1909. The rate for 1905 was 47.94; 1906—45.77; 1907—31.55; 1908—24.85; 1909—21.22. The death-rate among employees for disease has fallen from a maximum of 121.5 in July, 1906, to 11.13 in December 1909.

Of the yearly expenditure of $250 per capita, I estimate that $200 per capita is spent on mosquito work. This expenditure has accomplished the total eradication of yellow fever. The last case on the Isthmus occurred in Colon in May 1906. It has reduced the deaths from malaria in the total

\[310\] Malaria Prevention on Isthmus of Panama [Sec.

\[320\] Wages are high in Panama.—K. Ross.
RESULTS

Population from a maximum of 17.71 per thousand in July 1966 to 7.48 per thousand in December 1949.

Among employees it has reduced the deaths from malaria from a maximum of 11.75 per thousand in November 1948 to 1.32 per thousand in December 1949. The admission rate per thousand in July 1966 was 26 per thousand and in December 1949.

The admission rate per thousand for malaria among employees has been: 11.75; 11.75; 11.75; 11.75; 11.75.

Wherever in this article, I have used the expression 'per thousand' for a month, I mean on the basis of a year.

I would say the death rate was ten per thousand for July, 1966. I mean that if the number of deaths and population had continued the same for the year that they were for July the rate would be ten per thousand per year.

I think that the mosquito work already done at Panama, Honduras, Panama, and other places has demonstrated that malaria can be controlled and eventually banished from even the worst places in the tropics, and this at no very great expense. I think that the individual farmer can go anywhere in the tropics and be free from malaria if he will drain the land and clear brush within a hundred yards of his house. And in addition screen his house so carefully that mosquitoes cannot gain access. This will not cost him anything like as much as he expends in protecting himself against the cold of Dakota or Manitoba.

Notes on R. Ross—In H. B. Colter, the distinguished developer of 'Mosquito Anophelines' in the tropics, and most recently Director of Hospitals in the Panama Canal Zone, wrote me a letter from which I am permitted to quote the following: 'Independently of the general results as shown in the general statistics, there have been some number of isolated examples of the results of anti-malarial work. Caballo, for example, affords from an admission rate of 17.75 per thousand in July, within two months, from 48 to 52 per thousand death rate, and in July and December the same; in July, the death rate being 26 per thousand and constant almost throughout the year.'
in French times, one of the most healthful places from 1906 on. It was beautiful work. Not all were used by any means, but healthful work all the same. It is work, however, that depends absolutely on the perfection of its details (like aseptic surgery). See also Dr. Carter's article (page 12) for a brief but clear analysis of the operation.

A. E. Jordan, M.D., has kindly informed me that the Panama Anopheles, which are yellow and of white wing, are of Aedes echinatus of (Cohn) or (Cusson) A. echinatus, A. (Cusson) or (Cohn), A. (Cusson) or (Cohn). See also his papers "Jaedes," 57, 6, and "Notes," 17, 12.
Anti-malarial Work on the Isthmus of Panama;  

Technics.—As we approach the tropics, where the rate of growth of vegetation and rainfall increases, the cost of maintaining open ditches and keeping them free from *Aedea* larvae increases considerably. In the north the greater part of the rainfall occurs at a season of the year when mosquito life is dormant. Well-made surface ditches will need very little attention, and those having a fair grade will often be dry during the greater part of the *Aedea* breeding season. Here we have conditions that are different, and which are very favourable to the development of mosquito life. Our rainy period lasts for seven or eight months. The ground remains wet for many days at a time, and the dense vegetation prevents evaporation of surface water to a large extent. Most of our ditches contain water continuously throughout the wet season and well into the dry season. It is not unusual to have rain or showers occur during twenty-six days out of thirty. Such conditions keep the vegetation in open ditches growing rapidly, and are favourable to the development of growths of algae. The latter play a prominent part in the development of *Aedea* larvae. If the ditches are not kept free from vegetation, *Aedea* larvae will generally be found, and the number thereof seems to increase when algae are present. It is necessary to have as few ditches as we can possibly get along with. The flatter the ditch the more the likelihood of it becoming a propagation area. Also, as we know that the larvae have the habit of collecting in
A:">TIALARIAL

WORK ON ISTHMUS OF PANAMA [Sec.

still water, or in water having a low velocity, it is necessary
to keep the ditches of uniform cross-section and free from
obstructions. If this be not done larvac from up-stream will
probably find safe resting-places at points lower down. At
times, when all other insect life has been washed down-stream,
these larvac may be seen clinging to the bank of the ditch.

In connection with open ditches, it should be stated that
hard showers of short duration are a temporary help in that
deey clean out the ditches and remove all larvac. Very often,
however, hard rains will practically ruin a ditch and make
regrading necessary. A most important source of Anopholes
on the Isthmus is the seepage water that seeps up hill-
sides or on low ground near the foot of a hill. Such productive
areas may last for short or long periods, and may occur at
irregular intervals. If the quantity of seepage water be small
it may not be noted. In case it occurs near a settlement,
such an area, even though small, may and often does become
the cause of a large increase in the previously low malarial
sick-rate; and, moreover, extra attention will probably be given
to anti-malarial work at more distant points, while the real
source of the trouble may have escaped attention.

Sub-drainage is far superior to open ditches in every way,
and should be used whenever conditions are favorable therefor.
It is much more economical and better than the application
of larvicide under such conditions as exist here, for it is
always possible, even with the most careful inspection, for
numerous small seep areas to be missed.

The practice here is to cut off seepage water by means
of intersecting ditches containing drain tile. In all cases
locations and plans of such ditches should be made at the
height of the rainy season, when the worst conditions occur.
If this is not done errors will surely be made, and during
extra long rainy periods seepage water will occur on the up-
hill side of the tile line. Ditches for sub-drainage must be

\[ \text{water which seeps out} \rightarrow K. \text{Ross} \]
cut to true grade, and should be made as narrow as possible so as to reduce the amount of cover stone needed. The tile should be laid to true grade with open joints of about 1/8 inch, and then be covered with stones corresponding to field stone of about 4 to 6 inches in diameter. The dirt from the trench must be placed on the downhill side of the tile line to prevent it washing back into the ditch. When the soil uphill from the ditch is covered with vegetation the space between the cover stones does not fill up. Water will find its way into the tile line through the joints. We find that the flow of water in drain tile thus laid always carries such fine silt and sand as enters through the joints of adjacent sections, provided the grade is about 1/2 for 1-inch tile and not less than one half of 1′ for 1/2-inch tile, when there is no loose soil above the line of the ditch. Special care should be taken to have the outlet of the tile kept clear at all times. When tile drains are located and laid properly they are the most economical method of drainage for anti-malarial work, and the cost of maintenance is very small. Some drains laid three and a half years ago have not cost one cent for maintenance since installation. Due to wash-outs, erosion, incrustation of frequent regrading, cleaning, removal of vegetable growth, algae, etc., the cost of maintaining open ditches is often expensive and necessarily continuous. If such maintenance costs are or will be excessive, and conditions such as grade, character of soil, etc., are unfavorable for sub-drainage, we make the ditches the shape of a flat "V" and line them with flat stone laid in just sufficient cement mortar to hold them together, leaving sufficient weep holes near the rounded corner to take care of ground water. Frequently here the cost of maintaining an open ditch for two or three years will be more than that of lining the ditch permanently with flat stone. Near some of the camps such lining of ditches costs from 25 to 50 cents per running foot, and as the same ditching cost previously about 25 cents per foot per year to maintain,
the advantage of the permanent work is self-evident. Stone-lined ditches are very seldom sources of Anophelae. Filling is sometimes necessary in low lands that cannot be drained, and under certain circumstances it should be accomplished, providing the cost is not prohibitive.

A large number of Anophelae larvae may occur on flat lands where water collects in small quantities in numerous places. Although much of the water may evaporate, and the breeding-places dry up before the larvae can develop into adults, yet what usually happens is that a sufficient number of the small wet places remain, which, taken together, will produce during the rainy season sufficient adult mosquitoes to keep a near-by settlement well supplied. All very small as well as large wet places that are not thoroughly dry during a period of ten days need attention.

Evaporation of the surface-water can be largely increased by the removal of the vegetation. In fact, in many such areas we find that the larvae develop only when the grass and vegetation are sufficiently high to retard evaporation. Where the water continues to remain after the removal of all vegetation it will often be necessary to apply larvicide. In case the breeding areas cover a large territory, the transportation and proper application of the larvicide may cost several times more than the larvicide itself. Then it becomes necessary to use some form of concentrated larvicide in order that the labourers may employ nearly all of their time in applying it rather than in its transportation. After much unsuccessful experimentation with commercial larvicides it was found that a mixture of carbolic acid, resin and caustic soda has very satisfactory larvicidal properties and acts promptly. It meets the conditions that we have to contend with fairly well. It costs less than one-half of the best commercial larvicide we could obtain, and the latter was apparently not standardized. One part of this mixture placed in five thousand parts of water containing mosquito larvae will kill them all in less than five minutes.
When one part is applied to eight thousand parts of water containing larvae, the same will be killed in thirty minutes.

The method of preparing it is as follows:—Crude carbolic acid, containing about 1/4 of phenol, is heated to 212 degrees F., finely powdered resin is added, and the mixture kept boiling until the resin is all dissolved. Caustic soda is then added, and the solution kept at 212 degrees F. for about ten minutes, or until a perfectly dark emulsion without sediment is obtained. The mixture is thoroughly stirred from time to time until cooled until the end. As the composition of crude carbolic acid varies greatly, the proportion of ingredients of the larvicide will vary, and it is necessary to have a small experimental larvicide in the laboratory, and tested before the batch of larvicide is made for use in the field. The average mixture is as follows:—300 gallons crude carbolic acid; 200 lbs. resin; 50 lbs. caustic soda. The larvicide costs us about 14 cents a gallon.

In lagoons, ponds, and lakes near settlements, we get rid of the vegetation as far as possible, and at the edges where the water is shallow, and in other places where larvae occur, we destroy them with this larvicide.

When numerous small particles of dead vegetable matter that are washed into lakes or ponds are collected by the wind, the Anopheles lays her eggs in amongst this debris, and it must be removed.

In long running streams and open ditches where anti-malarial work is being done crude petroleum may be used, and it is more effective when applied automatically. Should the quantity of running water be small, so that not much oil is needed, then a handful of cotton waste tied in a bundle is soaked in oil for a day, and then placed near where the water crops. The water passing by this waste becomes covered with a very thin film of oil. The waste is washed off the oil film by about ten or fourteen days, and is then resoaked in oil and used again. For larger bodies of water having a fair
ANTIMALARIAL WORK ON Isthmus of Panama Since velocity, drip cans or drip barrels are used, and should be located 2 feet above the water surface to break up the oil drops as they fall. They are made as follows: A piece of metal similar to that of a flat wick lamp that holds the flat wick is fastened to the barrel or can near its base. This wick chamber is made somewhat larger than the wick, so that the wick may be cleaned when saturated with fuel oil. The space inside the barrel between the wick chamber and the bottom of the barrel, is filled with a solution of caustic soda or larvicide. As the oil passes along the wick it comes into contact with the caustic soda and is "cut" or rendered thinner. This prevents the wick from becoming plugged by the thick oil. The wicks seldom clog, but in case such occur some larvicide is dropped on the wick. This clears it, and makes it as serviceable as before.

Adult dengue may occur near settlements when it is suspected that all that is possible has been done toward their eradication. Near the seashore the larvel of some species of Aedes occur in water that is quite brackish. All brackish water should be considered capable of supporting dengue larvae until the contrary is proved to be true. Also mud from above which the water has recently disappeared should be looked on with suspicion, and treated when it supports mosquitoes. Many small muddy areas may contain no mosquito life, but if the larval are present in some small spots, the sum total of such possible places, most of which are hidden by the grass and not easily seen, is worthy of consideration. The adults that may develop therefrom in rainy periods are often numerous. Larvae may only be present in one or more particular parts of a large possible breeding-area, and a superficial inspection thereof will be misleading. Dipping with a cup is a very unsatisfactory way to determine the presence of larvae. Even when larvae cannot be dipped up from a small shallow body of water, if the same is stirred up the larvae will often appear promptly at the surface. When no larvae can be seen it does
not always mean that none are present. We use the larvicide application method to determine the presence or absence of larvae to a large extent. When applying strong solutions of larvicide at the edges of a large body of water it is noticed that the larva appears to lose all sense of direction. Very few reach the clear water, and nearly all that do so die soon afterwards. Our labourers are supplied with knapsack sprayers for distributing larvicide, and a labourer can take enough larvicide along with him to last for several hours of spraying. The cost of spreading a dollar's worth of crude oil by hand often amounts to two dollars or more.

As far as we can determine not much malaria is actually contracted by labourers while outside on the work. In fact we have no case on record when a person has been bitten on the Isthmus by an *Anophela* when the person was exposed to the direct rays of the sun. Although we think very little infection is conveyed during working hours in the sunlight, we do know that it is a common occurrence for persons to be bitten in the daytime by *Anophela* when both are inside of buildings. We have noted that a person indoors may be bitten several times in a period as short as ten minutes, and that *Anophela* while indoors will take blood at any time between daylight and dark, as well as at night.

In connection with the prevention of malaria, the destruction of adult *Anophela* in barracks, tents and other crowded quarters is certainly worthy of attention. The screening of buildings is of importance. To keep the screening intact and effective is quite a problem where ignorant labourers are concerned. A screened building is far superior to a preventative measure to the use of mosquito bars over each cot. The latter, as used by labourers, is generally of little value. The American housewife on the Isthmus is interested in keeping the screened doors closed in order to keep out mosquitoes and flies. The children and wives of American employees have been particularly free from malaria, and in fact do not contract malaria...
During February of 1907 a census of American women and children then in the territory between Bocas and Balboa was taken. There were 552 women and 345 children present. Some of them had come to the Isthmus in 1904 and 1905, but the greater part in 1906. The malarial sick-rate in 1906 and 1907 was very much higher than it is today. Among the 897 women and children, 82% had not had malarial fever between the time they arrived here and up to the time the census was taken. During the same period some of the laborers' camps had a 60% malarial hospital sick-rate per week. Of the American children on the Isthmus in February 1907, 76% had not yet had malaria. At Balboa, where the houses were not screened, there were seven American children and seven American women in February 1907. Three of the women and three of the children had had malarial attacks since arrival at Balboa.

A temporary camp consisting of tents was established at Cocoli during April 1907. Anopheles breeding-places occurred on all sides, and we could not possibly get rid of them without considerable expenditure of funds. The size of the camp did not warrant much expenditure. Adult Anopheles were very numerous about the camp, and thirty or more could be counted in a single tent in the daytime. A watchman was employed to kill off all mosquitoes seen in the tents during the daytime. This watchman kept on the go from tent to tent. All mosquitoes in the tent were within reach, which was a very important advantage. No work was done by the watchman after 4 p.m. At first Anopheles were so numerous that a tent could not be left for a half-hour without some coming in. The near-by breeding-places were oiled in order to reduce the number of adults, but many remained. The destruction of adults began 10th April 1907, and between that time and 24th August 1908 there were seventeen cases of malaria at Cocoli, which would mean only a little over $\frac{1}{2}$ of the force were sick with malaria during each
DESTRUCTION OF ADULTS

period of seven days. The camp was abandoned on 24th August 1908.

This was a lower sick rate than had occurred at other camps where anti-malarial work had been carried out for quite some time, but as we were killing adult mosquitoes, and the other places were not.

As this work resulted so successfully it has since been carried out at labourers' barracks at various stations, and has undoubtedly been an important item in the marked decrease of the malarial rate that has occurred during the past year.

Recently six hundred Anopheles (mainly allipoe) were collected alive in various camps where the adult Anopheles were systematically destroyed daily in barracks. They were examined by Dr. C. T. Burling, Chief of the Board of Health Laboratory, and not a single malarial parasite was found in any of the Anopheles between the time they first entered the barracks and the time when they should become infective. The catching of adults in the buildings which have high walls or in dark rooms is a much more difficult proposition than their destruction in low tents, where all can easily be seen and reached. It would be a large advantage to have the interior of buildings painted a light colour or white-washed so that Anopheles could be readily seen when resting on the walls. We now use test-tubes containing cotton wool and chloroform to destroy adults resting on walls, etc. It is quieter than the slapping method, and very few mosquitoes are frightened away.

At the base of Diablo Hill is a swampy area about two miles long and a half a mile wide. It cannot be drained at the present time. From the top of the hill to the water-line is about 200 yards. In June of 1908 several hundred United States Marines were stationed at Camp Diablo, and remained on this hill for about six or eight weeks. The conditions affecting malaria, such as drainage, etc., were then the same as they are to-day. While the Marines were in the camp their malarial sick-rate
was 2½ per day, or 14 per week. Since that time a string of railroad cars in which the laborers of the railroad construction gang slept was located near the foot of the hill, and between the swamp and the camp formerly occupied by the Marines. During the past thirty weeks an average of forty-four Anopholes per day have been destroyed each morning in these cars. They were caught in elytron tubes as above described. It takes the laborer thirty minutes each morning to do this work. The cost is 5 cents per day, or 30 cents per week, and the destruction is carefully performed by a competent man. From the first week in May 1910 to 30th November 1911, which is the rainy season, only four cases of malaria have occurred among the forty laborers sleeping in these cars, or about one man in 300 men working for a period of seven days, although they were more freely exposed to the Anopholes than the Marines had been. This work of destruction of adults in quarters costs so little that undoubtedly it will be of value in all malarial districts where house tenants are interested in the prevention of malaria. It will be of special importance where an army is in camp, or where railroad camps are established in malarial districts, as with proper care the sick-rate could by this means be kept far below what it would otherwise be. On the Isthmus we consider such work as supplementary to the drainage and other anti-malarial measures.

It should be noted that most of the laborers' camps in the Canal Zone are located near native towns, and undoubtedly a large percentage of what malaria we do have is contracted by our laborers spending their evenings at, or living at, the native settlements. Nevertheless, in spite of continuous topographical changes, constant rains, native villages and numerous other difficulties, the malarial sick-rate is being steadily and systematically decreased year after year. The decrease of adult Anopholes to be found at the camps is equally noticeable.

Several years ago it appeared that the malarial sick-rate would always be much higher during the rainy season than in
the dry season, but during the past two years the Department of Sanitation have been able to control the situation to such an extent that at some of the larger settlements there has been no appreciable increase in the number of malarial cases during the wet season as compared with the dry season. It is of interest to note that this has occurred in those districts where during previous years the increase of malaria closely followed the increase of rainfall. This is very encouraging, considering that such results have been obtained where the settlements are scattered over large areas.

With regard to the destruction of adult Anophelines in dwellings it should be stated that malaria cannot always be controlled by this means only, although it was fairly successful at Diablo and Cutoli. The colour of the house walls, height of the ceiling, the amount of light in rooms and the number of hiding-places, etc., affect the percentage of adults that may be destroyed.

Again, if persons living in houses that are inspected daily visit houses that are not so treated, or are infected elsewhere, the results will not be as satisfactory as where their camp is isolated as was the case at Cutoli and at Diablo. Drainage and eradication of breeding-areas is the most important work in an anti-malarial campaign. The catching of adults should be considered as supplementary to drainage, screening, application of larvicide, etc. At Havana we relied exclusively on drainage and filling. Most of the natives do not like to take quinine. Malaria at Havana has practically been eradicated.

Data relating to charts showing reduction of malaria in the Canal Zone—Chart No. 1 shows the percentage of all Canal employees (malarial cases only) that were sent to the hospital each month from 1906 to 1909 inclusive. Attention is limited to the fact that the sick-rate is always lowest about May or at the end of the dry season. That the malarial sick-rate would advance rapidly in former years with the arrival of the wet season June, July and August. This advance has been materially checked. Compare the wet season record of 1909 (June to December) with the same period of the previous years.
and with the dry season of 1909 (January to May). The successive yearly reductions are a fair index of the value of the anti-malarial work.

The successive months are plotted one half inch apart, horizontal measurement. The percentage malarial sick-rate is plotted on the vertical lines, on a scale of two inches vertical measurement, equals 1%. If the force employed consisted of 40,000 men, and 500 of them are sent to the hospital with malaria during a month, then the rate on Chart No. 1 for that month would be plotted as 1.25%. Chart No. 2 is a record of malarial cases among employees at Porto Bello. The percentage sick-rate for each week plotted. This was a new camp that was opened up a few weeks before anti-malarial work started. At all newly opened camps the malarial rate runs high, as compared with areas where anti-malarial work is being done. Without doubt the rate would remain high if no anti-malarial work were done. Note that preventative work at Porto Bello started 21st March 1908, and that the rate from then to June averaged, say, about 1% per week. Or, over 1%, of employees were sent to hospital per month (malarial cases), and many of the labourers remaining at work were not in physical condition to do as much work as they are capable of doing to-day. That during this same period, among employees in the Canal Zone, the monthly sick-rate (malaria only) was not much over 1%. (See Chart No. 1.)

About 600 men are located at Porto Bello. Chart No. 3 is a record of malaria at Gorgona. Present population 2,000 employees. Compare years 1908 and 1909 with the previous years. No large increase of malaria occurs in the wet season (June to December) during the last two years. Anopheles are now seldom found in barracks, which indicates that they are not numerous. Note the effect of the wet season on the malaria rate for 1906, and absence of same for wet seasons of 1908 and 1909.

In Charts No. 2 and No. 3 the weekly sick-rates are given.

*The accompanying charts are reduced—R.R.C.
RESULTS AT PANAMA

For instance, during the week ending 6th January 1906 a number of the employees at Gorgona (Chart No. 3) were sent to the hospital whose cases were diagnosed as malaria. This number consisted of 27.4% of the entire working force living at Gorgona during that week. The dates of the ending of each week for which the percentage sick-rate is plotted are given. These percentages show only the malarial sick-rates and not the other hospital cases.

In connection with Chart No. 3 it should be stated that in the early days it was difficult to get the malarial patients from among the ignorant labourers to go to the hospital, and so the actual sick-rate at that time was higher than what has been recorded. At the present time the labourers go voluntarily to the hospital when they feel sick. Note that during seven months of 1906 the rate was above 6%; that during 1907, for ten months, the rate was below 5%. In 1906 during eleven months, the rate was below 4%. In 1905, the rate was below 3%. The highest monthly rate during the wet season of 1909 was a little over 29%, as compared with 4.5% and 10% respectively for the wet season of the years 1906, 1907 and 1906.

Refer again to Chart No. 2, relating to malaria at Porto Bello. During December of 1909 the number of rainy days was twenty-seven out of thirty-one. The rainfall was 45.03 inches for November and 53.17 inches for December 1909, as against 41.73 and 27.79 inches respectively for November and December of 1908. Such conditions of rainfall mean a large increase in the number of possible Anopheles areas. As shown on the chart, no increase of malaria occurred due to the increased wet area accessible to Anopheles.

This is a good illustration of the results of anti-malarial work performed under severe conditions when the work might at first sight appear to be almost impossible to accomplish. From 1st November 1908 to 31st January 1909, 22% of the force were sent to hospital with malaria. From 1st November 1908 to 31st January 1909, 50% of the force were sent to hospital with malaria. From 1st January 1910, during the period of heavier rainfall, only 3.26% of the force were hospital malaria cases.
44. Malaria in the West Indies. — There is no doubt that malaria has markedly decreased throughout the West Indies. This statement can be verified by comparing the current health reports with those furnished by the Surgeon-Generals when the various islands were first settled. The facts, which have brought about this diminution are the same as those which have, in more recent times, operated in towns like Bombay, New Orleans, Rio, etc., and which at a still earlier period led to the disappearance of malaria from a large portion of Europe.

It may now be stated that malaria as an endemic disease is limited to the country districts throughout the islands, and that it occurs at the outskirts of the principal towns, in a few instances, penetrating into a centre of population along the banks of some neglected marsh or stream.

In the principal towns the swampy ground which almost invariably surrounded the early settlements has now all been reclaimed, and in its place well-planned streets have appeared. Properly graded roads and concrete drains are the rule rather than the exception. Since the year 1870 a considerable portion of the larger towns received the immense advantages of a pipe-borne water-supply, derived from reservoirs or rivers outside the town. This system at once did away with the old-time wells, and abolished, or greatly decreased, rain-water barrels and storage tanks. These improvements, coincident
with the progress of prosperity and the appreciation of the laws of hygiene, have together brought about the cessation of malaria and yellow fever as endemic diseases in the chief towns. Therefore it is in the country districts, and on the plantations, that the student must look for the survival of malaria in its endemic form. And there is no doubt that it does still survive throughout the Antilles, as an analysis of the Returns absolutely proves. Unfortunately, it is very difficult to estimate accurately the total sickness and mortality rates from malaria in the various islands; in many instances the cause of death in 50% or more of the cases is not definitely stated.

And, of course, as is well known, although the anaemia of malaria may have had the chief share in producing lowered vitality, yet the actual cause of death is registered as perhaps bronchitis or consumption, as the symptoms of these affections were the more obvious ones from which the patients suffered during illness.

Efforts are now being made, however, to make more accurate estimates of malaria by the employment of more perfect methods of diagnosis, such as sphen rates and blood examinations.

**Grenada**—Population, 69,213. Capital, St George's; population, 2,116.

Malaria is still prevalent in the country districts, and is endemic and imported. In No. 1 District in St George's Parish 681 cases and 27 deaths were recorded in 1906, and 317 cases and 12 deaths in 1907. In No. 0 District 1,119 cases were reported in the same year. The malaria is due to the breeding of Anophelines in certain swampy lands and puddles, and, in the wet season, perhaps also to the presence of water-holding epiphytes upon the shade trees on the cocoa plantations.

**Preventive Measures:**

1. Introduction of pipe-borne water. This was the first step which led to the reduction of Anophelines in the
towns of St George's, Grand Anse and Grenville by doing away with numerous barrels and old water containers.

2. Road-making and street drainage in the towns.

3. Government and medical officers throughout the colony making returns of all anti-malarial measures taken in their respective districts.

4. On 1st April 1904—The fish 7 million were introduced into the colony with the object of stocking ponds and large collections of water.

5. The Public Health Ordinance of 1907 prohibited the keeping of stagnant water unless protected, clogged or stocked with fish, and all odd receptacles were to be removed.

6. In 1902 and 1903 further ordinances were promulgated, declaring mosquito-breeding places in and about human habitations to be a statutory nuisance.

7. The more careful cultivation on the cocoa estates has led to better drainage, and a diminution of malaria on the estate.

8. Considerable attention is now paid to entomology.

**GRENADA, ST. VINCENT**


Malaria for the most part confined to small, swampy districts in the country. The Medical Officer's return show 525 cases in 1907, and 281 cases in 1908.

**Precautions:**

1. Pipe-borne water has led to great diminution of water barrels and old receptacles and wells.

2. Construction of side drains and tanks.

3. Removal of odd receptacles from yards, and better sanitary supervision.

**Antimalarial measures:**

1907—Measures promulgated against stagnant water, unless clogged, screened or stocked with fish.
New Public Health Ordinance, with provisions against stagnant water and mosquito larva.

The late Dr Branch was a keen entomologist, and did much to get rid of breeding-grounds of mosquitoes.

St. Lucia—Population, 50,000. Capital, Castries.
There is still a small amount of malaria, due to a few low-lying, swampy patches which persist near Castries.


Prophylaxis —
1. Introduction of pipe-borne water brought about a great reduction in the number of breeding-places.
2. Better roads and side drainage undertaken from 1890-1900.
3. Energetic anti-mosquito drainage and bush clearing operations undertaken by Major Hodder.
4. Anti-mosquito laws.—In 1906 the Colonial Secretary commenced a vigorous systematic campaign against mosquitoes, by causing careful returns to be made of all insect-carried diseases and of the breeding-places of mosquitoes.

In 1907 regulations were framed dealing with stagnant and waste water.
In 1909 a vigorous house-to-house campaign amongst mosquitoes was started.
Fines have been regularly enforced from 1907 against all who, after caution, refuse to get rid of mosquito larva.

Trinidad.—Population, 350,000. Chief Town, Port of Spain; population, 70,000.
General death-rate for 1906, 30 per mile.
Total deaths from malaria, 71 in 1906. Total amount of malaria small.

Upon the estates, however, malaria is responsible for more than half of the gross sickness rate amongst the indentured labourers.
This system was first introduced into the Port of Spain as far back as 1851, and has since then been largely extended throughout the Port of Spain. To it must be ascribed the abolition of endemic yellow and malignant fevers, for it at once did away with the necessity of the numerous water barrels, cisterns, wells and odd receptacles of all descriptions, which in the old days were the breeding-places of the mosquitos.

The construction of well-graded roads and concrete drains everywhere within the vicinity of the town.


5. Education.—Systematic training of the sanitary inspectors, schoolmasters and others throughout the colony.

6. Anti-larval law.—In 1900 regulations were made against stagnant water and larvae, enforcing the screening or sealing off fish stocking of stagnant water which could not be got rid of.

In 1907 a new Anti-Larval Law was passed strengthening these regulations, and numerous fines have been inflicted for contravention of the Mosquito Bye-laws.


Malaria, the principal disease of the colony.

In 1907 the deaths from malaria were 301.

Prophylaxis:—

1. Construction of good roads and drains.

2. Pipe-borne water-supply to George-Town not completed.

3. Fish stocking of all waterways.
4. Education, and training of sanitary inspectors, teachers, school, etc.

5. Sanitary supervision, removal of odd water receptacles.

6. Provisions Ordinance.—In 1901 Bye-laws were introduced enforcing proper drainage in George Town; later these were extended to the country districts.

The Nevisians.—In 1907 an Ordinance was introduced to render compulsory the screening of vats, and this law was enforced in 1909.

7. The distribution of quinine.

Barbados.—Population, 100,342. Chief town, Bridgetown.

It is stated on good authority that there are no Anophelines present in the island.

Malaria is not endemic; imported cases of malaria are common amongst the laborers returning from Panama. The absence of Anophelines is attributed to the very porous nature of the soil throughout the island, which prevents the formation of puddles. The ponds which are met with are all apparently stocked with "millions."

In Bridgetown the streets are well drained and kept flushed.

Water.—An abundant and excellent pipe-borne water-supply was introduced into the colony many years ago, and has since been extended. It strikes at the root of endemic yellow fever by putting an end to the innumerable odd water receptacles which were everywhere abundant.

In 1909 a vigorous anti-mosquito campaign was started, and the Anti-stagnant Water Ordinance of 1909 was rigorously enforced.

Sanitary inspection was increased, and a general cleansing and removal of all odd water receptacles carried out.

The Bahamas.—In 1905 measures were adopted against mosquito-carried diseases, and in 1907 anti-larval regulations were enacted, and screening, eilling or fish stocking of stagnant water enforced. Quinine was also distributed.
JAMAICA, BRITISH HONDURAS

For Northern Islands.—In 1903 vigorous action was commenced against mosquitoes.

Jamaica.—Population, 669,456; Capital, Kingston.

Anti-malarial measures in Jamaica. In October 1903 a special commission was appointed to investigate and to take measures to remedy the conditions which gave rise to malarial fever in different parts of the island of Jamaica. The commission consisted of the Colonial Secretary, P. C. York, Archbishop Nattall, the Superintendent Medical Officer, Dr. Kerr, Dr. Lyton and Dr. Graham, and Messrs. Gideon and Hart. Mr. Isaac was made official Secretary of the Commission.

The objects of the Commission were to ascertain the breeding-places of Anophelines, and to suggest the carrying-out of remedial and preventive measures; also to conduct investigations and to take evidence if necessary. The Commission had power to expend up to £100.

British Honduras.—Chief town, Belize; country very swampy.

Prophylaxis:

1. Anti-malaria work was commenced in 1903, and has been kept up with marked success.
2. A mosquito destruction Ordinance was passed in 1906. Owners of property were compelled to screen, oil, or deck with fish all collections of water.
3. Drainage and filling-in operations have also been started.

Bush clearing was enforced.
45. Malaria in Jamaica—The chief factors which influence
the prevalence and distribution of malaria in Jamaica are, first,
the physical configuration of the island, and second, the methods
of cultivation, which are necessitated by the requirements of its
forms of agriculture.

The centre of the island is occupied by a lofty chain of
mountains trending generally east and west, from which spurs
are thrown off running north and south, with intermediate fertile
valleys; while the east is occupied by flat alluvial land of varying
extent. From the mountains a number of streams, some of
considerable size, rush precipitously down till they reach the
lower plains, where they frequently form extensive grass-grown
swamps and open into the sea by a series of shallow, sluggish
mouths, in all of which malaria-carrying mosquitoes breed in
great abundance.

Moreover, it is naturally in the alluvial plains that the staple
industries of the island, namely, banana and sugar plantations,
are carried on. In the north-eastern portion, where the land is
almost entirely under banana cultivation, there is a heavy rain-
fall, and the soil is stiff and clayey. In consequence, the banana
plantations have to be deeply trenchd for the purpose of subsoil drainage, and the trenches, unless properly graded and kept clear of grass and weeds, afford suitable breeding grounds for Anopheles.

In the south and south-eastern parts of the island different conditions obtain. The rainfall is small, and irrigation, both on banana and sugar estates, is imperative. Here again the channels, unless properly supervised, are a prolific source of mosquitoes.

Among minor factors may be mentioned the ponds formed by surface drainage, invariably grass-grown, and used sometimes as the water-supply of a village, and more frequently as cattle ponds; and the shallow, water-logged, weed-clogged gutters along the sides of the streets of the villages and towns.

General malarial death and sickness.—Although the extensive prevalence of malaria in certain districts of Jamaica has long been recognised and its seriousness as affecting not only the general health and the death-rate of the community, but the industrial development of the colony, was fully appreciated by the medical profession, yet, apparently from the apathy of the locality, no attempt appears to have been made to make an accurate malarial survey of the island, and preventive measures were practically non-existent. In the latter part of 1897, however, an expedition from the School of Tropical Medicine of Liverpool visited the island, and thanks to the active cooperation of the Government and of the Island Medical Service, a systematic though limited survey was made, and much useful information was obtained. The following statistics are mainly taken from one of the reports of the expedition by myself (Ann. Trop. Med., 1898, No. 9, 17th November 1898).

The total malarial deaths for the whole island for a period of ten years amounted to 34,695, which is equivalent to a malarial death-rate of 4-4 per 1000. The general death-rate during the same period was 22-6. The average percentage of malarial to total deaths was 19-7, representing nearly one-fifth of the total deaths.
A summary of the statistics is given in the following table —

### Average Death Rate, Etc., for the Decennial Ending 1905-1909

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Admissions</th>
<th>Total Deaths</th>
<th>Mortality Rate per 1000</th>
<th>Malaria Admissions</th>
<th>Malaria Death Rate per 1000</th>
<th>Typhoid Admissions</th>
<th>Typhoid Death Rate per 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904-05</td>
<td>18,552</td>
<td>306</td>
<td>1.67</td>
<td>4,837</td>
<td>0.26</td>
<td>239</td>
<td>0.01</td>
</tr>
<tr>
<td>1905-06</td>
<td>22,106</td>
<td>375</td>
<td>1.69</td>
<td>6,168</td>
<td>0.29</td>
<td>380</td>
<td>0.17</td>
</tr>
<tr>
<td>1906-07</td>
<td>22,583</td>
<td>415</td>
<td>1.84</td>
<td>7,383</td>
<td>0.32</td>
<td>380</td>
<td>0.17</td>
</tr>
<tr>
<td>1907-08</td>
<td>23,510</td>
<td>450</td>
<td>1.92</td>
<td>8,729</td>
<td>0.37</td>
<td>390</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>77,755</strong></td>
<td><strong>2,721</strong></td>
<td><strong>3.53</strong></td>
<td><strong>27,915</strong></td>
<td><strong>0.36</strong></td>
<td><strong>1,560</strong></td>
<td><strong>0.20</strong></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>19,437</strong></td>
<td><strong>680</strong></td>
<td><strong>3.53</strong></td>
<td><strong>6,978</strong></td>
<td><strong>0.36</strong></td>
<td><strong>390</strong></td>
<td><strong>0.20</strong></td>
</tr>
</tbody>
</table>

But the prevalence of malaria is really much greater than is indicated by the death-rate, for of the admissions to the Government hospitals of the colony, it is found that at least one-third are due to malaria, and the malarial sick-rate shows a marked increase of recent years.

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**MALARIA IN JAMAICA**

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It is calculated that the cost of the maintenance and treatment of the malarial cases alone amounts to over £6,500 per annum.

On basing and sago estates the loss of time the sug allure mainly malarial and therefore preventable, amounted to sixteen out of every hundred working days per male labourer employed; while among the coconut settlers, a picked body of men, it is estimated that there is a loss of nearly four thousand days' service per annum from the same cause.

The spleen rate.—That the endemic index of the island is high is shown by the results of the examination of the spleens of children. Among 2,976 children examined in all parts of the island, 536 were found to have enlarged spleens, a spleen rate of 18%. But if the mountainous centre of the island were to be excluded, and places on the littoral only taken, the spleen rate would be found to be much higher, and in certain localities rises as high as 30%. The following table summarises the results of the splenic survey:

<table>
<thead>
<tr>
<th>District</th>
<th>No. of children examined</th>
<th>No. with enlarged spleens</th>
<th>Total No. of enlarged spleens</th>
<th>Average spleen rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bengal</td>
<td>246</td>
<td>172</td>
<td>179</td>
<td>72%</td>
</tr>
<tr>
<td>Penang</td>
<td>300</td>
<td>235</td>
<td>235</td>
<td>78%</td>
</tr>
<tr>
<td>N. Penang</td>
<td>44</td>
<td>32</td>
<td>32</td>
<td>72%</td>
</tr>
<tr>
<td>N. Perak</td>
<td>205</td>
<td>148</td>
<td>148</td>
<td>72%</td>
</tr>
<tr>
<td>S. Perak</td>
<td>220</td>
<td>167</td>
<td>167</td>
<td>75%</td>
</tr>
<tr>
<td>Negri Sembilan</td>
<td>200</td>
<td>137</td>
<td>137</td>
<td>69%</td>
</tr>
<tr>
<td>Malacca</td>
<td>194</td>
<td>132</td>
<td>132</td>
<td>68%</td>
</tr>
<tr>
<td>Penang</td>
<td>184</td>
<td>122</td>
<td>122</td>
<td>66%</td>
</tr>
<tr>
<td>Malacca</td>
<td>182</td>
<td>119</td>
<td>119</td>
<td>65%</td>
</tr>
<tr>
<td>S. Perak</td>
<td>176</td>
<td>110</td>
<td>110</td>
<td>62%</td>
</tr>
<tr>
<td>S. Penang</td>
<td>176</td>
<td>110</td>
<td>110</td>
<td>62%</td>
</tr>
<tr>
<td>Total</td>
<td>4,986</td>
<td>3,477</td>
<td>3,477</td>
<td>69%</td>
</tr>
</tbody>
</table>

A complete splenic survey, in order to obtain an accurate idea of the distribution of malaria, is one of the first steps to be taken in any anti-malarial scheme.

1 See section 31 (a).
MALARIA IN JAMAICA

Any material measures. To diminish the extensive prevalence of malaria the following measures have been recommended as being particularly applicable to the requirements of Jamaica:

1. To make the harboursing of mosquitoes into compounds a punishable offence.
2. To keep all margins of rivers and swamps in the neighborhood of towns free from grass and weeds.
3. The application of crude kerosene where possible.
4. The screening of wells, tanks, etc.
5. The cementing of gutters in towns.
6. The gradual reclamation of swamps.
7. Screening of public hospitals, police stations and cooke barracks.
8. Prophylactic administration of quinine to police, coolies, school children and the general public.
9. Education in sanitation and hygiene, all of which would be under the supervision of a central anti-malarial organisation.

As already stated, up to the beginning of 1909, little in this direction had been done. Small quantities of quinine had been distributed to certain for prophylactic purposes, but had not been given systematically and continuously; a few isolated efforts at swamp reclamation had been made by private individuals, and one police station had been made mosquito-proof, but there was no concerted or systematic effort to stamp out malaria.

As a result, however, of the attention which was drawn to the subject by the expedition from the Liverpool School, probably assisted by a severe outbreak of malaria which occurred in the spring of 1909, public interest appears to have been awakened, and in the autumn of that year the first steps were taken to deal with the disease in an organised and systematic manner. His Excellency the Governor appointed a Commission, consisting of the Colonial Secretary, the Archbishop,
of the West Indies, the Chief Medical Officer, and other medical men, to enquire into the subject, and to take such steps as appeared to be urgently necessary. A series of public lectures have been given, which has done much to spread a knowledge of the disease in different parts of the island; a new Public Health Ordinance has been passed; steps have been taken to train sanitary inspectors in the recognition of the breeding places of Anophelines, and anti-mosquito measures; and, most important of all, in February 1910 a sum of £5,000 was voted to carry out the various measures necessary. So that now we may consider that the anti-malarial campaign in Jamaica has been fully started, and the outlook for the gradual elimination of malaria in the island is distinctly hopeful.
Hy. It WOLFESTAN THOMAS, M.D., C.M. WIGELSTON,
Of the Liverpool School of Tropical Medicine Research Laboratories,
Manaus, North Brazil.

46. Malaria in the Amazon Region, and the Protection of Ships.—Malaria prevails throughout the Amazon region. The chief industry of this part of South America is rubber, and the immense trade requires a large number of men to collect the crop. The conditions under which they work cause many privations and expose them to infection. The old saying that every kilo of rubber represents the loss of a life is an exaggeration but there is an enormous mortality amongst the "cahuchas" who work in the interior.

In the vast territory watered by the Amazon River three places of importance occur, which serve as the commercial centres for the upper traffic of the interior. Iquitos, 3,200 miles from the mouth of the Amazon, is the only large town in Peru on the eastern side of the Andes. Manaus, on the Rio Negro, some 200 miles distant from the mouth of the Amazon River, and Para, which lies near the mouth, are in Brazil, and possess the only hospitals for the accommodation of the up-river patients. No attempts have been made by the states of Amazonas and Para to create any hospitals along the rivers in the interior of the rubber districts. They are very necessary, but their establishment is hindered by reason of the enormous expenses involved.

Iquitos has no pipe-borne water-supply, and the drainage is of the most primitive character. Extensive swamps extend in and about the town, but no attempt has been made to fill them.
The majority of the cases appear to have contracted malaria up river. The cities of Manáos and Pará receive many cases of malaria from the interior, and consequently their death-rates are unduly high. Both cities suffer from the return of the infected rubber-collectors, who go and live in the suburbs along the swamps; they either neglect all treatment, or take an insufficient amount of quinine, and, living in a state of poverty and misery, they lie to their mud huts exposed to the bite of numerous mosquitoes.

Their blood contains many gametes, and they therefore serve as infecting agents for the Anopheles that feed on them. Their presence is a menace to the community, as they may cause most virulent epidemics of malignant types of the disease. Manáos is intersected by many creeks and swamps. Those in the center of the city are completely filled, but, on the outskirts of the city proper, certain creeks and swampy areas still form foci of malaria. In the suburbs extensive swamps exist, and very severe forms of malaria prevail. A modern system of drainage and water-supply exists, and has done much to mitigate the evils.

**Table: Malaria Index of Children in Swamp and City**

<table>
<thead>
<tr>
<th>Swamp</th>
<th>Blood rate</th>
<th>Hygienic Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swamp (apparently healthy)</td>
<td>3/75</td>
<td>4/74</td>
</tr>
<tr>
<td>Swamp (apparently ill)</td>
<td>2/01</td>
<td>3/50</td>
</tr>
<tr>
<td>City Swamp</td>
<td>12/42</td>
<td>35/40</td>
</tr>
<tr>
<td>Children living along swamps in suburbs</td>
<td>4/10</td>
<td>5/52</td>
</tr>
<tr>
<td>Children living along swamps in suburbs of city</td>
<td>5/15</td>
<td>5/45</td>
</tr>
</tbody>
</table>

The state and municipal authorities are gradually destroying the Anopheles breeding-places within the city. Free advice and medicines are given to the poor, but no steps have been taken to organise a campaign against the hordes of Ceratitis and Anopheles, which especially the former are the carriers of malaria throughout the whole of the Amazon region.

At Porto Velho, on the Madiera River, a railway is being constructed to connect Polivas and Brazil. Several attempts have been made to build this line, and each time malaria has raged amongst the workmen. A most virulent form of fever occurs which has at times incapacitated up to 80% of the total working force. The difficulties in combating the disease are great, and are increased by the possibilities of importing yellow fever from Manaus, Nejia, or Para. The line is in the interior, through virgin forests and large swamps, an organised attack on the lines of the anti-mosquito campaign of Panama and Xerec in South Brazil would facilitate the progress of the undertaking. A graphic account of some of the past unsuccessful attempts is recorded by Craig.

Belém or Pará possesses a pipe-borne water-supply. The swamps are numerous above the outskirts of the city. In 1909 the authorities were influenced to undertake the filling of much swampy land, and to institute free distribution of quinine. A most serious outbreak of malaria occurred amongst the poorer inhabitants living in the outskirts of the city, along the swamps of the Marco de Leba, Pardas, and Canudos, etc. A medical commission traced the outbreak to the arrival in Pará of many labourers who had returned in an infected condition from the Madiera-Mamora railway and Atlantic works. These people went to the outskirts, and, living in a state of squalor, they remained untreated, and quickly infected the numerous Anopheles of the locality. Practically every one in the district

Craig, Neville B.: 'Recollections of an Unsuccessful Expedition to the Head-Waters of the Madeira River in Brazil.' (Lippincott.)
suffered from malaria. Free clinics were opened, and in four months nearly 13,000 people were treated with quinine; the very severe cases were sent to the hospital. Endeavors were made to have all patients with enlarged spleens confined in the hospitals, or screened from mosquito. Mosquitos were kept and all gametocyte carriers were energetically treated with quinine. A brigade was formed to fumigate the dwellings of heavily infected individuals, and a general purification of the surrounding yards and houses was made. Measures were taken to drain and fill the pools and swamps of the most heavily infected districts, and as many breeding-places as possible were destroyed. A great and general improvement was noted after a few months. The number of infections and the number of Anophelines diminished, and it is to be hoped that these satisfactory results will encourage the authorities to continue their efforts. The expenses were about £4,540, which was expended on clinics, hospital accommodation, drugs, draining and filling of pools, swamps, etc.

The inhabitants of the Amazon region take very little care to avoid contracting malaria. They frequently neglect to take quinine, or discontinue it after a few days of treatment. The labouring class Brazilian hardly ever uses a mosquito net, and, unfortunately, Europeans are prone to follow their example. In Iquitos, the Peruvian labourer generally protects his bed, not because of malaria, but for relief from the swarms of *Anopheles triannulus* and *Culex fatigans*, which are veritable pests; this helps to account for the less pronounced infection of the Peruvian.

All through the Amazon region, where large engineering works have been undertaken, the old familiar story has been repeated. Not only has money been wasted, but many lives have been sacrificed by the neglect of the promoters to realize the dangers of malaria and Anophelines. The astute commercial man has still to learn that it is cheaper as well as quicker to organize a scientific force to combat malaria or yellow fever, and to have such a force in operation before any attempt is made.
to import labourers and commence the work. The Federal authorities have clauses regarding quinine prophylaxis, screening, etc., in the contracts with the concessionaires, but these clauses are frequently neglected. Many important engineering works are certain to be undertaken in the opening up of the country in North Brazil, and an endeavour should be made to prevent the waste of life which has hitherto occurred. The sanitary authorities of both the Amazon and Pará states are alive to the necessity of combating the disease by extermination of the Anopheles.

2. Protective of ships. - Very little attention has been devoted to the protection of the crew and passengers of steamers navigating regions where malaria prevails. On some steamers mosquito-nets have been provided for the bunks, and a few wire-screened doors for the outside cabins, which are not and chart-room. These are inadequate, as they do not protect the entire living quarters of the passengers and crew.

The screening of a steamer is a difficult undertaking. Four facts must always be remembered:

1. That the navigation and working of the ship should not be interfered with.
2. That the scheme of screening shall be as simple as possible. Elaborate designs are certain to fail, as they cause much trouble and inconvenience to those on board. The members of a crew or even passengers will neglect to carry out complicated methods of closing doors and port-holes.
3. That the maximum amount of air shall be available. In the tropics the closeness of the atmosphere does not encourage the average individual to reduce the ventilation by the interposition of wire-gauze screens. I have seen on a steamer plying to the Pacific large screened wooden frames, designed to fit in the port-holes, but so massively constructed that the cross diameter was reduced nearly one-half. It is barely
to be expected, since so much air and light is cut off that the crew will make use of the screens.

(4) That an endeavour should be made to screen the vessel in sections, so that, if mosquitoes succeed in obtaining an entry, they can only circulate in that part of the ship and can be hunted down and destroyed.

Mosquitoes generally board a ship when it is moored near it shore or in hugging the banks, and they quickly find their way to the saloons and living quarters of the crew.

All parts of a ship which communicate with the danger zone, i.e. the open deck, should be protected. The doors should be screened, and where there is much passing to and fro between a protected area and the danger zone, a second door should be placed some 5 or 6 feet away, thus forming a windbreak, and allowing one door to be closed before the other is opened. All doors should be provided with spring-locks which catch easily, and a strong door-spring to create a rapid and tight closing of the door. If the storm-doors are left open, care should be taken that the hatches do not impinge upon the wire screens and so tear or fray the gauze.

The ventilations leading to the cabin, saloons, etc., should be screened at the ceiling level.

Through the courtesy of the Booth Steamship Company, the plans of a vessel specially screened against mosquitoes are shown. The ship is designed for use in ocean and river trade in a district severely infected with malaria and Anophelines. The port of call is far away, and it is notorious for the severity of the malarial infection. It is the outcome of the experience gained by Dr Neville Davidson, Medical Superintendent of the Company, to whom I acknowledge my indebtedness.

All the port-holes of the cabins are provided with removable screened frames, which are so adapted that the port-holes can be closed and screened down without necessitating the withdrawal of the screens. The frame of the screen consists of a metal hoop, on which gauze is tightly stretched and soldered. The
frame is provided with rigid bayonet catches, which are so arranged that they slip easily into the ordinary port, and a half turn of the screen is sufficient to lock it.

All the ventilators, as is seen in the drawings (figs. 1-4), are screened by a most simple and efficient arrangement. Ordinary circular moulding is fastened on the ceiling around the vent pipe; the moulding has a deep groove, into which fits a round metal frame covered with wire-gauze; the screened frame is retained in position by three small buttons, so that it can be instantly applied or removed.

The screen doors have light wooden frames and panels of wire-gauze. They are provided with spring-hinges and strong coiled wire door-springs.

By reference to the accompanying plan (figs. 5, 6) it will be seen that the arrangement of the screening is quite simple and yet adequate. The screened port-holes and doors are outlined in black. The only entrances to the saloon, chart-room, captain's cabin, pantry and bath-room, are through a screened door on the port side, another on the starboard side, and a third at the foot of the stairs leading from the wheel-house. The outside cabins are all shown with screened doors and port-holes. Further aft, and isolated by the steam-steering gear, are the cabins of the doctor and hospital.

On the main deck the entrances on the port and starboard sides through which the crew must pass to their work are screened. On the starboard side there are two sets of screened doors along the alleyway. These are provided because the ash-discharger is open to mosquitos and therefore constitutes a danger zone. On the port side this extra screening is unnecessary, as in the river only one ash-shoot will be used.

A study of the plan will show that the only unscreened parts of the ship communicating with the interior are the engine-room, stoke-hole and galley. Theoretically, these sections should be screened, but two factors must be taken into account, viz., the intense heat of the places, which is always accentuated in the
S.S. "VINCENT."

SECTION OF SHIP SHewing MOSQUITO NETTING TO DOORS AND PORTS.
1 MOSQUITO PROTECTION FOR
VENTILATORS AND PORTS.

"VINCENT."

Fig. 1

VENTILATOR

Fig. 2

Fig. 3

Fig. 4

TS AND PORTS

To Face Page 348
PROTECTION OF SHIPS

Tropics, and the coal-dust, that would cake and block the meshes of the screen, and thus restrict the inlet of air. The wheelhouse is unprotected, as screening would be impossible when navigating a river.

Provided the screening is not disturbed very few mosquitos should be able to gain an entry, and adequate regulations can be made to prevent such acts as the taking off of a port-hole screen or tying back a door.

For port-holes an 18 mesh should suffice, and the gauge of wire need not be thicker than 32 or 30. For doors which are liable to be roughly used, a heavier gauge wire is necessary. The mode of application of the wire-gauze is important. The gauze should not be tacked on to the frame. A far better method is to have a deep groove running around the panel /2 3/, and a rail either of wood or metal of a size slightly smaller than the groove. The wire-gauze is laid over the rail and the rods driven into the grooves. This makes the wire taut and the tension is equally distributed. All strands of the mesh are fastened securely, which is not the case with gauze fastened down by tacks. Over the rail a neat strip of moulding can be fixed, which finishes off the panel and can be easily removed. The great advantage of this method is that it is a comparatively simple matter to take off the strip of moulding, remove the rods, and substitute another piece of gauze. This method is extensively used all through the United States.

Excellent arrangements for large private yachts and even passenger steamers can be devised. I have seen nearly the whole of the bridge deck enclosed with ordinary mosquito-netting. The top was made of tarpaulin stretched on rods, and the sides were made of gauze. At sunset the sides were let down, and from fifteen to thirty people were able to dine and sleep in comfort. The expense is not so great, and is amply compensated for by the relief from mosquitos.

Messrs Tohn Holt & Co. have recently screened an entire ship for West Africa.—E. Ems.
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47 Prophylaxis of Malaria in Central and Southern Brazil.—Several anti-malarial campaigns have been carried on under the technical direction of our Institute, all of which have been crowned with the most complete success. They were undertaken in the following chronological order:

1. In the construction of the Itatinga Railway, Santos.
2. In the works of damming the River Negro and Manicoré, for the water-supply of the city of Rio de Janeiro.
3. At the time of the extension works of the Brazilian and Northern of Minas Railway.
4. During the survey work for the Bahia and Espirito Santo Railway.
5. During the construction of the North West of Brazil Railway.
6. In the suburbs of the city of Rio de Janeiro in connection with the prophylaxis of yellow fever.

The most important campaigns were conducted by Drs. Carlos Chagas, Arthur Neiva and Gomes de Faria. Members of the Institute; and Dr. Carlos Chagas (1906-1907-1908) had already written on some of them, he being among us the first to organise a scientific campaign against malaria. The prophylactic formulae adopted by the Institute comprised the following:

1. Prophylaxis by quinine exclusively, adopted when the treatment had to be applied to a moving population.
and one not remaining any length of time in a particular zone (railway constructed).

(2) Preventive administration of quinine, isolation of the persons infected with quinine, in infirmaries fitted with wire-gauze, and unrelaxing treatment of those infected. This system was adopted when the persons already infected had to reside for some time in the infected zone with healthy persons, and where the work was done more slowly.

(3) The same measures as above, together with systematic sulphur disinfection of infected dwellings. Prophylaxis adopted when the staff remained for a longer period in the infected zone, and where it was not possible to carry out prophylaxis by means of larvae.

(a) Indirect prophylaxis by war on mosquitoes.

Let us see more in detail how these prophylactic systems were carried out among us.

The first prophylaxis—Quinine—This was put into execution with success in the surveys for the South of Bahia Railway, by Drs. Mauroz de Abreu and K. Scholze, of the General Board of Public Health. The process consisted in the daily administration of 0.06 grammes of sulphate of quinine. It was compulsory, and the medicine was administered by the doctors themselves, who saw that the patients swallowed the capsule. In this case, as the persons never remained long in the same place, the dose of quinine given was always prophylactic, which is not the case when the persons remain for a long time in the same infected places, as we shall see later. In the special case, the results were most complete; not one of the persons subjected to the regime fell sick, whereas others who accompanied the party, without belonging to it, and who would not submit to the same prophylaxis, were attacked by malaria.

The second prophylactic formula—Here the process followed out included —
(1) The preventive administration of quinine, in the dose of 50 centigrammes every three days.

(2) The isolation of the persons infected with gametes, in infirmaries protected by wire-gauze during the hours the Anophelines sting, being subjected to strict treatment until the gametes disappear.

(3) Early and radical treatment of persons infected for the first time and not themselves infectious (this was done without isolation), in order to prevent them becoming infectious to mosquitoes by the formation of gametes.

Dr. Neiva, who was entrusted with the carrying out of the quinine prophylaxis on a large scale (among some 3,500 workmen at Xerém), observed that among those treated with quinine cases of first infection began to appear and increase rapidly. He was able to verify these positively by excluding the cases of temperature noted after the beginning of the campaign. Satisfied that the dose of quinine was not sufficient to guarantee the prophylaxis, he proceeded to administer it at intervals of two days; after some time, fresh cases of first infection began to appear, and these were only really stopped when he commenced to administer the quinine in a daily dose of 50 centigrammes.

It is interesting to note that among the persons thus treated with quinine an outbreak of malaria occurred when they discontinued the use of quinine, even though the practice had been continued after leaving the infected zone; and to prevent such attacks it became necessary to continue the use of quinine for a long time, and repeat treatment at intervals. Stranger still, persons who, after leaving the malarial zone, went to reside in places which were certainly not infected, when under the action of quinine they

MALARIA IN CENTRAL AND SOUTHERN BRAZIL [Sec. 7]
had no fever, but harboured plasmodia in the system. Dr Neya, in view of his observations, admits that during the quinain prophylaxis the plasmodia become gradually accustomed to the quinine and immune against this poison, giving rise to a family able to resist the quinine, similar to the families of trypanosoma which defy atoxyl. Subsequent to this interesting observation of Dr Neya's made in October 1917 several other authors have referred to analogous facts.

The occurrence of the new infection could not be attributed to the inefficient administration of the quinine. This was compulsory, and was administered by trustworthy persons, the infections being found to exist in persons who undoubtedly had taken the prescribed doses.

The second item of the prophylactic formula under consideration is intended to destroy the gametes in circulation, which prevents the infection of the mosquitos, which, as we know, can only occur when there are gametes in the periphery. This result was obtained by the daily and continued administration of 50 centigrams of quinine. It was proved by the microscope that after a time it was no longer possible to recognize the existence of gametes, whether of the benign or of the malignant tropical tertian. When the parthenogenesis of the gametes occurred, following an excessive work or heavy rains, a gramme of quinine was given daily, as a rule by intramuscular injection. It should be noted that no scabs appeared after the injections.

The above shows the necessity of carrying on the anti-malarial campaigns by persons capable of making the utmost use of the assistance furnished in such cases by the microscope.

The third prophylactic formula—Dr. Carlos Chagas, in his studies on the epidemiology of malaria, and on the biology of the Aedes responsibile for the transmission of the trouble within the zones, found that there were dwellings constituting regular hot-beds of malaria, and that such houses were invaded by mosquitos infected with the plasmodium of malaria. To combat the trouble in such cases, the following formula was given:—

The method employed by quinine is well known.—R. Ross.
at night by the *Anopheles*, which stayed there till dawn, some withdrawing to the woods, whence they returned the following night, others remaining concealed in the dark damp places of the huts.

These infected mosquitoes caused the permanently infected conditions of these dwellings. The opinion that malaria is a disease commonly infectious in houses finds a perfectly feasible basis in arguments relating to the biology of the *Anopheles*, and in numerous facts arising from careful observation. In view of this Dr Chagas resolved to make systematic cleaning by sulphur fumes in such dwellings, and thus succeeded in eradicking these centres of infection.

These measures were always accompanied by quinine prophylaxis. But as an experiment Dr Chagas ascertained that the treatment of dwellings by sulphur was sufficient to prevent the infection of the persons who passed the night in such deadly centres of malaria, and who were not subjected to the action of quinine.

The fourth prophylactic formula.—This consists of indirect war against malaria by the destruction of the larves of the *Anopheles*. This prophylactic system was tried at Rio de Janeiro, when the prophylaxis of yellow fever was carried out in the metropolis of Brazil. One part of the war on mosquitoes was begun by drying up all temporary deposits of water, the destruction of the larve in natural deposits by means of the cultivation of larve-devouring fish (Lemnoria constricta major), by the protection of indoor water-systems from mosquitoes, the poisoning of large sheets of water, the destruction of the *Anophelus gypaphes*, etc.

The results obtained were very favourable, as may be seen by an examination of Table No. 1, which we give below. In Table No. 2 is given the complete result of the anti-yellow fever campaign. The malaria figures do not show the same decrease as those for yellow fever, because in the table for malaria the cases existing in the urban hospitals, where
patients were received from rural zones not influenced by the prophylactic campaign, appear:

Table II.

Table III shows the results obtained in the campaign undertaken at the time of the damming of the Rivers Xerem and Mantiquera for the water-supply of the city of Rio de Janeiro. The region through which canalisation work had to
be exterminated was so devastating by malaria that 44% of the men employed in the work were attacked, the mortality being so heavy that the Government was obliged to abandon the first attempt. Work could not be resumed until special prophylactic service for malaria had been organized, with the result that in a few months the works were completed and the city of Rio de Janeiro provided with an abundant supply of drinking water.

In the malarial zones of Brazil the following species of *Aedes* are found: *Culex perniciosus* Thomson, *Culex fatigans* (Theob.), *Culex intermedicus* (Chagas), *Culex argenteascens* (Theob.), *Culex abnormis* (Wirth), and *Aerihalpago pseudomansonia* (Theob.) (Chagas).

These are undoubtedly the transmitters of malaria, as was experimentally shown by the characteristic forms of evolution of the plasmodium in them.

The following species are suspected of transmitting the malaria, so far as can be judged by epidemiological studies: *Marcympius laticlavius* (Theob.), *Culis breviserru* (Chagas), *Myrrhomyia titi* (Cros), *Myrrhomyia perrea* (Chagas).

As to the habits of the *Aedes*, Dr Chagas noticed that as a rule they work only at certain hours, at nightfall, when they come in swarms, or in the early hours of the morning. They disappear entirely during the day and night, at which time, therefore, there is no danger of men being infected by the contaminating mosquitoes, or of the mosquitoes being infected by sick persons with gametes. An exception to this rule is the *Culis brasiliensis* (Chagas), which attacks for preference during the day and in the sun, which fact shows the necessity of studying the *Aedes* fauna of the region in which it is proposed to start an anti-malarial campaign.

Further details as to the Brazilian *Aedes* and their relations with malaria may be found in the works of Dr A. Neiva, lately published (1903).

In dealing with the organisation of the systematic prophy-
318 MALARIA IN CENTRAL AND SOUTHERN BRAZIL [1907: 47

laxis against malaria a knowledge of the existence of the

Mycoplasma lutea (Thur.) in the region is deserving of special

attention.

This mosquito, which appears to be responsible for the

transmission of malaria in the regions where there are no

swamps, lives in the waters found in the Ecnomus gruppus

(Lutz, 1902), and is so small that it can pass through the wire-

gauze of 15 mm. mesh, usually employed for protection of

houses. For this further reason it is advisable to study the

Anopheles fauna of the region before proceeding to instal

mechanical prophylaxis of malaria.

Finally, it should be mentioned that the quinine prophyl-

axis has been carried out without the slightest inconvenience

to the persons subjected thereto, there being a large number of

people who have used daily 30 centigrammes of hydrochlorate of

quinine for the last two years and ten months without showing

the slightest bad effect from the employment of this medicine.

Further, the phenomena of nausea in the ears, etc., are not

observed when the quinine is administered at meal

hours. No cases of haemoglobinuria have been observed following

the administration of the quinine, and the few cases of this morbid

tissue observed disappeared with the quinine treatment.

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### RESULTADOS DA CAMPAHIA ANTI-PALUDICA NO XEREM

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O gráfico apresenta dados sobre a campanha anti-palúdica no Xerem. Os dados incluem os números de anos e os números de abastecimento de água na área.
By IAN MACDONALD, M.D., EDIN., M.D., PARIS

Huelva, Spain

48. Malaria in Spain.—Among the countries of Europe, Spain has always suffered severely from malaria, and the records of history show that it swept over her with the violence of plague. In September 1279, when Philip the Bold of France invested and took Gerona, his army was almost destroyed by pernicious fever, and he himself succumbed to an attack at Pamplona. In this epidemic, according to Duran, great importance was attached to "some fire which caused death by their fires." Of its ravages in the Peninsula no better picture has been given than that of Johnson in 1773, "the attack of Carthagena is yet remembered, where the Spaniards from the camps were destroyed by hostility of the elements; poisoned by the air and crippled by the dew; where every hour swept away battalions; and in the three days that passed between the descent and the embarkation half an army perished." From historical data, it is clear that the greater number of Spanish authors up to the eighteenth and first half of the nineteenth century in many cases confused malaria with the whole group of infectious diseases. In those times one Spanish clinician, Ludovic Mercado, physician to Philip II and Philip III, stands apart from the rest; for in 1608 he differentiated pernicious intermittent fevers of tertian type in the midst of the pathological chase around bhed, In 1773 Mascavall described the lamentable effects of malaria in Lérida and the devastation it caused among the French troops massed in Lerida. He pointed out the relation
MALARIA IN SPAIN

between fever and the pools left by rivers and after rains, are remarked that the greater number of cases were always found amongst those who worked in the sun and who slept at night in the open air. He completes those accurate observations by recommending the use of Peruvian bark for the cure of the disease.

In the first years of the nineteenth century (1800-1805) several papers appeared on the value of quinine in epidemics of yellow fever, and Nelson in one of his last letters to Lady Hamilton, writes of "the dreadful effects of yellow fever at Gibraltar, and in many other parts of Spain."

Though *Aedes aegypti*, the carrier of yellow fever, exists in the cities of Southern Spain, from a study of the symptoms and course of this fever and the therapeutics employed by these authors, it is clear that they were dealing with severe types of summer-autumn fever with hepatic symptoms.

In 1865 discussions began in Spain as to the validity of Laveran's great discovery, and till 1866 the best paper on the parasite was that of Thin and Marshall, who accurately described the types of fever met with in Southern Spain. But the hypothesis of Laveran and Manson, as that date passing from theory to fact in the researches of Major Ross, received no support from these investigators; for their conclusions are thus presented in a well-known text-book (1899): "The observations of Thin and Marshall go to show that in the province of Huelva at all events heliothermal conditions are the permanent factor in infection, that the plasmodium is not usually conveyed by water, and that there is no evidence of the mosquito being an intermediary host." After the publication of Professor Ross's early papers, in the summer of 1899 we began to investigate malaria in the same province, over an area of 60 miles, extending from the Rio Tinto mines in the foot hills of the Sierra Morena to the coasts around the town of Huelva. In the hills it would be difficult to find a
more arid district, where water appeared to be completely wanting, for the vegetation within a three-mile radius had been destroyed by the fumes of sulphur smoke. It lies 320 meters above the sea-level, and the soil is sandy and stony. Hardly any rain falls from May to October (winter season), with the exception of rare thunder-storms.

The aspect of the country is that of undulating hills covered with low brushwood beyond the smoker area. The valleys in winter are often filled with roaring torrents. In summer these streams dry up, leaving pools, varying in size from about 1.8 ft. in diameter to the size of a plate or saucepan. The district is dotted over with small villages which are situated on the slopes of the hills. The whole area was more or less malariaous, but certain villages were notoriously unhealthy, and it was a curious fact that the lowest lying village was the healthiest, though the moving of earth for mining operations went on at its very doors. Yet half a mile off, where most of the British employees lived, fever was frequent. In September 1902, we showed that, so far from mosquitoes being scarce owing to the presence of sulphur smoke, they abounded in the district; and in the paludal villages *Anopheles maculipennis* was then the only mosquito to be found in the houses. In the Province of Huelva we differentiated the following varieties of mosquitoes: *Anopheles maculipennis*, *Anopheles superpictus* Grassi, *Myzomyia superpicta* Blanchard, *Wingomyia fasciata*, *Culex pipiens*, *Culex p. quinquefasciatus* (Gershuni quinquefasciatus Koeneni), *Culex pipiens* (Tiebouticus pipiens), *Culex quinquefasciatus* (Eiseni, T. pipiens, *Culex pipiens*).

In south Spain *A. maculipennis* is the chief carrier of malaria. *A. superpictus* is not often met with; we have only found it in three or four districts.

We have always found that the abundance of *Anopheles* in any district is in relation to the extent of malaria.

Since then, repeated observations in many places in the South of Spain have always shown us the same conditions in fever districts. Whether the town is in the hills or on the
MALARIA IN SPAIN

Plain, the dried-up water-course is always there, the pools sometimes covered with algae. In the hills the water is often running slowly. In the Sierra we have found _Anopheles_ larvae in rocky pools devoid of vegetation, but as a rule they contain algae at the edge of which the larvae swarm. The difficulty of seeing the larvæ of _Anopheles_ compared with those of _Culiseta_ is at once well known, and in some cases a careful examination is needed before concluding that there are none in the pool. In the hills, if a muddy pond and a clear one existed side by side, we constantly find the preference of _Anopheles_ for the limpid water. As a general rule we have not found larvæ in artificial collections of water — only very occasionally in old barrels and iron tanks on a railway line. In mining districts here, dams are often believed to be a source of malaria. We have not yet found larvæ in such collections of water, but larvae were observed there in the margins within 50 metres of the dam.

The adult _Anopheles_ in winter and spring hibernate here in stables, brick-kilns, and pig-sties, where they can always be found until the end of May or the beginning of June. After that time they are also found in the houses. The source of the epidemic wave of the malaria in Spain is unknown, as elsewhere, the strict relation there is between the human infection of the previous year (water relapses, calves, children) and the infection of the mosquitos in June and July, the beginning of the fever season. Our observations showed that the percentage of the infected _A._-pools in June was only 7.6, while towards the end of July and in August it rose to 10.

Of _Anopheles_ captured in stables, etc., none were found infected. We frequently found mid larvæ of _Hydroaedes_ fixed on the insects, and sections of some _Anopheles_ which died rapidly in captivity were examined by Laveran and were found to contain a fungus in the wall of the stomach and in the colonic cavity, which possibly may be pathogenic for the insect.

For infection experiments, we fed _A. maculipennis_ on fever
caused, and weak hematoce gave us good results in staining the zygotes. Sometimes no infection of the insect took place, or the zygotes failed to reach maturity. We felt that such variations were probably due to the diet of the mosquitoes, and a note by Seldon of Holland confirmed this, for he pointed out the importance of avoiding acid fruit in the food of insects under infect ex experiments, and when we fed them on melon, the growth of the zygotes was uninterrupted.

The role of Anopheles in Spain admits of no doubt, and the mosquito has never been found wanting in malarial districts in the fever season when searched for by competent observers.

These investigations were confirmed elsewhere in Spain by Huguet and Mendosa in the province of Léon, and by Pintados in Catalonia, Barcelona, Valencia, Madrid, and the Balearic Islands, where he found A. maculipennis, A. quadrimaculatus, A. superpictus, and A. riparius. In 1933 Pintados collected the investigations, up to date on malaria in Spain, and from the papers of different writers, in that volume some idea was obtained of the extent of malaria in modern Spain. His map gives a good idea of its distribution.

Through exact data are difficult to obtain, it is quite apparent that the disease still reigns with great severity in the Peninsula. In 1900 there were 2,967 deaths from malaria in Spain in a population of 27,833,000, which is a malarial mortality of 0.05 per mille. In relation to the general mortality of 21,523 316 per mille, this represents 1.14% of the general mortality, or 9 per 1000 of the cases of death. In 1907 and 1908, when the troops came back from Cuba, the malarial mortality rose immediately, and probably gave in each of these years a mortality of not less than 9000 per annum. The following figures from a railway company give a further idea of the ravages of malaria in Spain today. In 1902 1,204 employees were treated medically or surgically, and of these 1,162 were malaria patients. Five deaths were directly attributable to fever.
and the company lost 14,275 days' work in consequence of the disease.

On certain divisions of the line this company keeps a double personnel to alternate every fifteen days, and the employees themselves call one notoriously unhealthy area "Little Cuba," where their doctors admit that the mortality is equal to that of tropical countries.

After these researches some stimulus was given to prophylaxis, but, so far, in Spain it has only been undertaken by a few companies and private individuals. In a country where typhus last year entered its capital, and the isolation hospitals are unknown in her provinces, sanitation is only in its infancy.

In the city of Badajoz in 1893, in one street 300 people were attacked by malaria, and the supply of quinine ran short in the town. Yet no municipality has yet organised a scheme of prophylaxis.

Through the kindness of Dr Vasella we are enabled to submit the following figures from the Madrid, Zamora, and Alcante Railway, where protection of the railway servants houses by wire-gauze, and the administration of quinine, are the methods employed, and have given a gradual but steady diminution in the cases of fever:—

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<th>Year</th>
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<th>Cases after Protection</th>
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<tr>
<td>1893-94</td>
<td>631</td>
<td>70</td>
</tr>
<tr>
<td>1894-95</td>
<td>90</td>
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In Rio Tinto, supported by a company which recognises the importance of the health of their staff, we initiated measures of prophylaxis, on a small scale, which have been continued under the direction of Dr Russell Rivas, the chief medical officer with eminently satisfactory results. The English staff of the company, with their wives and families, number about 170 persons. They live in a group of thirty houses, in close proximity to the ravines where Anopheles pools are found.

A few years ago in the malarial season each house had its fever patient, and the place was notoriously unhealthy.
peaks are now filled up or drained away; and where it is impossible to remove the water completely, narrow channels are made by which a rapid flow is maintained, and stagnation prevented. Simple open drains have been laid in the bed of some watercourses. The use of nets is recommenced, and some families have their houses protected by wire cages. The effect on the number of mosquitoes has been marked, for now they are hardly ever seen. Hens, etc. and places harboring domestic animals are smoked out once a week by a mixture producing sulphurous acid gas. The diminution in the cases of malaria may be seen by reference to the following table which we owe to the kindness of Dr. Rent——

<table>
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<td>90</td>
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<td>80</td>
<td>20</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>1932</td>
<td>70</td>
<td>15</td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>1933</td>
<td>60</td>
<td>10</td>
<td></td>
<td>70</td>
</tr>
</tbody>
</table>

The attack on the Anopheles pools has recently been extended to the natural water courses and the villages, where a large number of men under supervision drain away and fill in the pools.

The improvement in the health of the people has been most marked. In former years departments with 7,000 men at times had hundreds incapacitated by fever, and difficulty was sometimes found in maintaining the service. Now though some cases still occur, fever never rises to the extent it did formerly. Villages which were recognized as hotbeds of malaria and consequently avoided by the workmen have been rendered comparatively healthy again. The cost of these measures in Rio Tinto and its environs is less than £100 per annum; but costs are lessened by assistance given by the various departments of the mine. Ten years ago there was a yearly despatch of 1,225 oz. of quinine; it is now reduced to 900 oz., though there is an increase of 30% in the number of workmen.
The Campaign against Malaria in Italy.—In my report to the International Congress, held at Brussels, I described how a Society for the study of malaria in Italy had arisen, and stated that it had initiated its work for the purposes of knowing better and vigorously combating this grave scourge of our country.

I have much pleasure now in noting summarily the results obtained from 1903 till to-day.

Since Ross's discovery was confirmed and consolidated by the work of some of our members, and later by many other workers, we have continued to work in the scientific and practical fields.

In the scientific field we have made researches on the etiology, physio-pathology, epidemiology and prophylaxis of malaria.

In the practical field we have introduced new and improved prophylactic measures into medical use, legislation and the habits of the people.

In order to keep within the narrow limits assigned to me, I can note only the following facts:

1. Owing to pressure of work, Professor Celli has asked me to take his contribution to this work by printing the Journal of Tropical Medicine for 1st April 1908 (translated by Dr John J. Eyre). The editor of the Journal has kindly permitted this. — R. Ross.

FIG. 1.—MORTALITY FROM MALARIA AND THE CONSUMPTION OF QUININE IN ITALY

1. Annual number of deaths from malaria from fifty upper part.
2. Kilograms of quinine imported by private mercantile firms from 1891 onwards.
I.—The Principles of Epidemiology

By our researches it has been demonstrated and confirmed in different ways that:

(I) Man is the only source at present known of malarial infection.

(2) Not only infants, but also children and adults, are the bearers of the infective germs.

(3) The recurrences, sometimes obstinate, in spite of every kind of treatment, are the most marked characteristic of every form of malarial fever. They maintain the contagion between the healthy and the diseased from one epidemic year to the next, and are one of the main causes which regulate the local and annual variations of the malarial epidemics.

(4) As the indication of an epidemic, it is necessary to take into consideration:

(a) The infantile malarial morbidity and the relative splenic enlargement: this splenic index, as it is named by Christophers and Stephens, may be easily ascertained, but is neither exact nor exclusive; moreover, it does not suffice, when alone, to indicate the intensity of an epidemic.

(b) The morbidity in the whole population or in some classes of it (country people, miners, soldiers, railway employees).

(c) The recurrent cases which are more or less obstinate.

(d) The numerical relation between the antico-autumnal and the mild tertian fever cases.

(e) The more or less severe clinical features and complications (haemoglobinuria).

(f) The manifestation of domestic epidemics or of sporadic cases.

(g) The total or absolute mortality, related to the whole population (relative mortality), or the one related to
the number of the infected individuals (pneumonia or lethality from malaria).

(4) Demographic indications, especially the excess of deaths over births and the following depopulation and devastation which are but too sad a characteristic of malarious lands.

When we take into account all these indications, we may every year not only exactly establish the course of epidemics in our districts, but also precisely compare our observations with the international ones.

An historical description of epidemics in these last years, by making use of the above-mentioned indications, would be possible only for small, well-circumscribed and thoroughly studied areas.

Therefore we must generally content ourselves with the mortality index, and, as far as possible, with the morbidity index too.

(5) The severe tertian, the mild tertian, and the quartan have each a special type of epidemic; that is to say, the first is auto-inoculum proper, the second is the only one which presents itself in the spring, the third is principally autumnal.

(6) The Anopheles are never wanting where the fevers exist, but their quantity is not always in direct proportion to the intensity of the epidemic; in fact, it is frequently in inverse proportion. On the other hand, there may be plasmodia and Anopheles without malaria developing itself, even when malarial patients arrive there from other places, or some autochthonous or sporadic case of fever manifests itself there. Plasmodia and Anopheles may therefore persist, and, notwithstanding this, the malaria may become attenuated and disappear.

(7) The number of Anopheles infected is always small, even in the places and months most affected by the fevers. The hereditary transmission of the infection from mosquito to mosquito has not been demonstrated up to now.

(8) Various annual epidemic types exist, namely —
(e) The South of Italy type, with great predominance of the autumn-autumnal parasites, with virulence generally excised.

(b) The North of Italy type, with more or less predominance of the parasites of the mild tertian and the initiation of this in the spring.

(c) The North of Europe type, with the absolute predominance of the mild tertian and the precocious development of the epidemic in the spring.

In Hungary, Greece and Russia epidemic types like those observed in Italy are met with.

(g) The mortality from malaria in the whole of Italy from 1887 onwards (cf. fig. 1, upper part) has been subject to regular periodic oscillations, with a maximum every five or six years. This periodic course is most marked in the most malarious regions—namely, from Latium downwards, and in the islands (cf. fig. 2), while in the rest of Central and North Italy the progressive descent without notable variations is manifest.

The morbidity also from malaria in the Rome hospitals is subject to periodic oscillations which in the last fifteen years have reached their maximum every five years.

No relation has been as yet established between the meteorological conditions and the annual and periodic epidemic oscillations, which would seem to be due more to general biological properties inherent in the specific parasites themselves than to climatic reasons.

(10) In the study of the malarial epidemics, besides infected men and Anopheles, it is necessary to take into consideration also other predisposing or immunising causes of biological or organic (x), physical or local (y), economic or social (z) origin. Although they are unknown in their intimate mechanism of action, nevertheless they have undoubted influence both on man and on Anopheles, and hence they may stimulate or impede the development of a malarial epidemic. Therefore, for the primary, very simple equation: Malarial man + Anopheles = epidemic of
malaria, we must substitute this other: Malarial man is a *Anopheles* x, y, z-epidemic of malaria.

The above-mentioned facts show that the problems of the epidemiology and prophylaxis of malaria cannot be considered from a narrow point of view.

11.—The Measures for Combating Malarial Epidemics

Our first attempts were directed to the destruction of the mosquitos by physical and chemical means. The laboratory

1 Compare lecture 28.—R. Ross.
experiments were encouraging. Later attempts, with great perseverance, were carried out by Galli-Valerio and by J.
Rochas de Jong, by biological means (animals and plants which
kill mosquitoes or impede their development). On carrying this
into practice on a large scale one meets with many difficulties
owing to which, at least among us, with so many extensive
marshes and so much intensive culture, one cannot succeed,
save in exceptional cases and by long and arduous work, in
destroying malaria by means of the destruction of mosquitoes.
Nevertheless, to the old and reliable methods of the campaign
against malaria, namely, drainage and agrarian sanitation, our
efforts were directed.

The hygienic effects of the sanitation by drainage already
carried out were studied. The result was that on large
extensions of land the best drainage sanitation very frequently
failed to drain off all the water or to give it sufficient velocity to
impede the aquatic life of Anopheles. Frequently, also, the
deficiency of the neglected state of the complementary drains
and of the discharging canals helped to maintain the anophelism.
Consequently, very often the drainage improvement is not
synonymous with sanitation, to which one will arrive in time,
when the agrarian sanitation supervenes, which, therefore, must
be the necessary complement of the drainage improvement.

Both, however, as we shall see, can, and should, be facilitated
and shortened — with insalvable saving in health and time
— by means of the medical, mixed, or at least the quinine
prophylaxis.

In its turn the agrarian sanitation helps to improve the
conditions of life of the worker by better housing, alimentation,
work and clothing. These coefficients, together with improved
medical assistance and the consumption of quinine, have led
after a long time, and now lead more quickly, to the sanitation
of a territory, even were paludism, with the relative anophelism,
still exists, and even can usefully exist, inasmuch as it helps to
render, by the utilisation of the waters, the agriculture more
prosperous.
Keeping away infected mosquitoes from the person and from the house is another mode of protecting oneself from malaria, which is directly derived from the new theory.

However, if man on whom this scourge weighs should wish to free himself from it only by the mode which is directly derived from the theory of the Anophelina, that is, by the destruction, or at least by the keeping away of these insects, who knows how long he would have to wait?

We refer to the difficulties met with by us in our campaign in endeavouring to destroy the mosquitoes.

A quicker and, within certain limits, a more easy method is to prevent them biting one by keeping them away. But only the minor part of the population, namely, the richer and, therefore, the least attacked, can enjoy this benefit.

In fact, in order to prevent the bites of mosquitoes one requires, above all, proper clothing, which frequently is wanting, and owing to the great heat cannot be supported; thus, also, the gloves and masks for protecting the uncovered parts of the body are very inconvenient, and prevent one working.

Oduors, ointments, and washes containing oxidized substances, which, according to our researches and those of others, are many, have a very restricted action in closed spaces, and little or no action in the open air.

On the other hand, he who can live in some kind of habitation, with all the openings protected with wire-netting to prevent the entrance of mosquitoes, can thus, as a rule, preserve himself from malaria.

This method, which was first adopted by us in 1899, by our advice is coming more and more into use in the houses along the railways, as shown from the appended table.

This mechanical prophylaxis has been adopted in the Custom-house officers' barracks.

It, however, is not equally practicable for soldiers.

Unfortunately, owing to the first cost and that of repair, it
is an expensive prophylaxis; besides, it presupposes a special hygienic education in those who inhabit the protected houses, and that they should retire there during the most dangerous hours of the day, things which are very far removed from the mode of life in which our peasants are accustomed.

**TABLE I**

**Mechanical Prophylaxis along the Adriatic Railway**

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent of patients</th>
<th>Percent of patients</th>
<th>Percent of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmers</td>
<td>Workers</td>
<td>Aborigines</td>
</tr>
<tr>
<td>1899</td>
<td>24</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>1900</td>
<td>10</td>
<td>10</td>
<td>65</td>
</tr>
<tr>
<td>1901</td>
<td>8</td>
<td>10</td>
<td>55</td>
</tr>
<tr>
<td>1902</td>
<td>3</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

Fortunately, much easier and quicker results can be obtained, when one wishes it, by the proper administration of quinine.

It is very well known that quinine is a truly sovereign remedy, both for disinfecting the blood of malarial patients and for provoking an artificial medicinal immunity. But this very powerful weapon with a double edge has not been well managed by others; whereas in our hands it has constantly increased in value, not only for the curative treatment, but also for the preventive treatment of malaria.

There is no doubt that this remedy acts in inverse proportion to the degree of development of the malarial parasites in the bloodstream; that is to say, it acts best against the sporozoites directly they are inoculated, and least against the forms destined to maintain the recurrent fevers, and little or not at all against the sexual forms destined to propagate the species. We have thus proved over and over again that some
fevers are pernicious in recurring in spite of the abundant and protracted use of quinine, either alone or associated with the so-called reconstitutents (iron and arsenic). In fact, these latter drugs, under whatever form and in whatsoever way administered, have no value as direct anti-malarial remedies. It follows from this that even the best treatments in the pre-epidemic stage do not succeed in preventing, as Koch thought they would, the development of malaria in the following summer. Therefore, by the quinine treatment alone to extirpate malaria from an extensive locality is much more difficult than one would a priori imagine. In any case, it must be the work of long duration, that is to say, treating in every period of the year, day by day, energetically and assiduously, every case of malarial fever.

Quinine, however, is the best remedy for the radical treatment of malaria, even latent and recurrent. The essential thing is to continue the treatment for a long time with great patience and perseverance; and the secret of success is to administer the quinine in the most agreeable and therefore also the most tolerable form. Besides, it is better, when possible, to call in the aid of other means pre-eminently beneficial, such as alimentation, habitation, clothing and moderate work. Since, therefore, the latent and recurrent infections cannot be prevented, much less eradicated, it is necessary to do everything to prevent completely the malarial infection itself. The quickest and best results regarding the preventive treatment are obtained by quinine administered for this purpose.

To establish firmly the scientific and practical basis of this preventive treatment of malaria has been, since 1900, one of the principal tasks we have undertaken. Thus, by degrees, with the assistance and control of able collaborators, we have come to the following conclusions —

(a) That quinine, provided it be administered daily, in average and even therapeutic doses better tolerated, and for a longer time than a priori one would have believed, that is to
say, after the first two or three days it no longer produces the least singing in the ears, and it is not only completely innocuous, but also acts as an aid to nutrition and as a tonic to the digestive apparatus and muscles, thereby increasing the appetite and the power of work.

(b) Quinine taken daily is always present in the blood, and thus prevents instead of producing the phenomena of quininism. Further, there is not, perhaps, another example of a remedy so perfect, nor one which so rapidly establishes itself, and can be prolonged for a long time (up to five or six months), and yet can be interrupted when desirable without any disturbance, and without, although the organism is habituated to the small and average doses, diminishing the curative efficacy of the large doses when they are necessary.

(c) But if quinine be given at intervals longer than three days the phenomena of quininism present themselves every time; in consequence the method of intermittent administration, namely, every four days (Ziemann), every five (Plehn), every seven to ten (Koch), although recommended by these able workers, is not preferable to our continuous and daily method.

The administration at intervals of every two or, at the utmost, of every three days (Sergent) may be in some cases employed. Longer intervals are not to be recommended, owing to the disappearing of quinine from the blood three days after the administration.

(d) Intolerance to the salts of quinine insoluble in water, if they be administered in average doses daily, is met with in very few persons, and up till now we have never observed the haemoglobinuria which the intermittent method and the relatively large doses have not succeeded in preventing.

(e) Intolerance very exceptionally manifests itself if a salt insoluble in water, such as tannate of quinine, be given. This salt is slowly absorbed, especially in the intestine, by the work of the bile and of the pancreatic juice, and it is perhaps for this reason that it has the value of being generally atoxic, even in
persons who have a special idiosyncrasy for haemoglobinuria towards the salts soluble in water. By reason of this ordinary toxicity, as well as the absence of bitter taste, it is specially indicated for young children, and for those adults who show intolerance for the other salts or suffer from malaria complicated by gastro-intestinal disturbances.

(7) According to Mariani and Giemsa also, quinine proper that is, in the basic state, is absorbed, and acts very well. Consequently, the solubility or not in water of a preparation of quinine, or its administration with the stomach full or empty, do not in the least deserve that importance which has been and is attributed to them.

(8) An essential coefficient of true tolerance is to administer it in an agreeable form, hence the forms of comfits or chocolates which we have persistently proposed for the various salts of quinine.

(11) He who takes quinine every day, and therefore has always a supply of quinine in the blood-stream, can undergo with impunity inoculations of blood full of malarial parasites, and can expose himself with little or no danger to the bites of infected mosquitoes.

Arsenic and iron do not display any protective antimalarial action, either experimentally or chemically demonstrable.

These are the scientific and practical facts on which we have based the method of preventing new infections, and of reducing the recurrences by means of the daily administration of quinine in average doses, namely:—40 centigrams of the bisulphate, hydrochlorate or bihydrochlorate of quinine for adults and young persons; 20 centigrams of the same salts, or 30 centigrams of tannate of quinine for children; and in every case administered in the agreeable form of comfits or chocolates. These, especially, owing to the sugar and cocoa have overcome the dread and prejudice against the prophylactic use of quinine.

1 See end of section 16 and section 55.—R. Ross.

2D
THE CAMPAIGN AGAINST MALARIA IN ITALY [cont.]

In districts with very severe malaria the above doses are increased to 50 or 60 centigrams for adults and young persons, and one can or must substitute the bisulphates for the hydrochlorate of quinine. In districts with mild malaria the indicated preventive treatment of children may be given on alternate days.

The efficiency of our method is demonstrated by the following figures, which show the rapidly increasing number of persons who, in virtue of the work of our members from year to year, have benefited by this preventive treatment.

### TABLE II

**Quinine Prophylaxis in Italy**

<table>
<thead>
<tr>
<th>Year</th>
<th>Persons treated</th>
<th>Percentage of control</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>116</td>
<td>58</td>
<td>Agro Romano and Pontine Marshes</td>
</tr>
<tr>
<td>1901</td>
<td>3.072</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>1902</td>
<td>35,950</td>
<td>43.35</td>
<td>Various parts of Italy</td>
</tr>
<tr>
<td>1903</td>
<td>44,458</td>
<td>34.15</td>
<td></td>
</tr>
<tr>
<td>1904</td>
<td>51,369</td>
<td>41.05</td>
<td></td>
</tr>
<tr>
<td>1905</td>
<td>55,312</td>
<td>42.02</td>
<td></td>
</tr>
<tr>
<td>1906</td>
<td>60,385</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>1907</td>
<td>65,397</td>
<td>43.89</td>
<td></td>
</tr>
<tr>
<td>1908</td>
<td>70,570</td>
<td>41.54</td>
<td></td>
</tr>
</tbody>
</table>

In its turn Table III demonstrates that in the Agro Romano, which has been the birthplace of this prophylaxis, owing to the initiative of our Society, the Red Cross Society and the rural doctors of the communes of Rome, while the number of immunised continually increased from 1900 onwards, the cases of primary fevers and of all malarial ailments treated by the Red Cross diminished. Further, the Rome hospitals
admitted a much smaller number of cases in the years 1901-1904, barely felt the usual quinquennial recurrence of 1905, and admitted a minimum number of cases in 1906.

TABLE III

<table>
<thead>
<tr>
<th>Qunine Prophylaxis in the Agro Romano</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
<th>1906</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar. Patients treated</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Feb. Patients treated</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Mar. Patients withdrawn</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Feb. Patients withdrawn</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Mar. Patients infected</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Feb. Patients infected</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
</tbody>
</table>

The unanimous agreement of both the doctors and patients during these last years have convinced us more and more that this daily quinine treatment diminishes notably the recurrence, causes the perennialism to disappear, prevents coccus, and very frequently the primary infections, and at least renders the fever milder and more easily curable by simply increasing the quinine for a few days to the therapeutic dose and then returning to the prophylactic dose.

Hence it is that from the Agro Romano, where we made our first experiments, the daily use of quinine, which is as necessary as daily bread in the district and nucleus of malaria, has to-day extended to every malarious province of Italy, and it is extending more and more among the rural populations, the State employes living along the railways, and in the Army. Its further extension to those who need it is a question of time, that is, of education and organisation. Inasmuch as, in order to convince oneself of its value, it is sufficient to try it, he who has done so proclaims its value and goes on using it, and thus by entering gradually into the habits of the country people, it acquires a wide field of beneficial action, especially among the
very numerous persons who, being without any kind of habitation, are compelled to live and work in insanitary places.

### Table IV

#### The Malaria in the Army

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of men</th>
<th>Recurrent</th>
<th>Primary</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cases</td>
<td>cases</td>
<td></td>
</tr>
<tr>
<td>1901</td>
<td>19,926</td>
<td>25,93</td>
<td>6,68</td>
<td>Initiation of quinine prophylaxis</td>
</tr>
<tr>
<td>1902</td>
<td>19,927</td>
<td>26,93</td>
<td>6,68</td>
<td>Continuation of quinine prophylaxis</td>
</tr>
<tr>
<td>1903</td>
<td>19,928</td>
<td>27,93</td>
<td>6,68</td>
<td>Quinine prophylaxis becomes excessive</td>
</tr>
<tr>
<td>1904</td>
<td>3,94</td>
<td>5,83</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>1905</td>
<td>3,95</td>
<td>5,83</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>1906</td>
<td>3,96</td>
<td>5,83</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>1907</td>
<td>3,97</td>
<td>5,83</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>1908</td>
<td>3,98</td>
<td>5,83</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>1909</td>
<td>3,99</td>
<td>5,83</td>
<td>2,75</td>
<td></td>
</tr>
</tbody>
</table>

1 Year of periodic epidemic recrudescence.

It is certain that it is much better to be able to live in protected houses, and to make preventive use of quinine. It is precisely this mechanical and chemical or mixed prophylaxis which is to-day in use along our railways, and is obligatory for

### Table V

#### Malaria along the Adriatic Railways

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage of cases treated</th>
<th>Days of ease due to types of malaria</th>
<th>Days of ease due to every year per person</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1901</td>
<td>90.92</td>
<td>7.88</td>
<td>6.48</td>
<td>Without prophylaxis</td>
</tr>
<tr>
<td>1902</td>
<td>65.35</td>
<td>6.71</td>
<td>5.18</td>
<td>Mechanical prophylaxis</td>
</tr>
<tr>
<td>1903</td>
<td>63.22</td>
<td>6.71</td>
<td>5.18</td>
<td></td>
</tr>
<tr>
<td>1904</td>
<td>57.95</td>
<td>7.83</td>
<td>6.96</td>
<td></td>
</tr>
<tr>
<td>1905</td>
<td>56.41</td>
<td>7.94</td>
<td>7.00</td>
<td>Mixed prophylaxis</td>
</tr>
<tr>
<td>1906</td>
<td>55.66</td>
<td>7.94</td>
<td>7.00</td>
<td></td>
</tr>
<tr>
<td>1907</td>
<td>54.89</td>
<td>7.94</td>
<td>7.00</td>
<td></td>
</tr>
<tr>
<td>1908</td>
<td>54.07</td>
<td>7.94</td>
<td>7.00</td>
<td></td>
</tr>
</tbody>
</table>

1 Years of periodic epidemic recrudescence.
the contractors of public works, and is gradually extending also among the rural administrations.

### TABLE VI

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Officers</th>
<th>Number of Cases verified.</th>
<th>Percentage</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1899</td>
<td>8,728</td>
<td>1,022</td>
<td>60.30</td>
<td>Without prophylaxis.</td>
</tr>
<tr>
<td>1901</td>
<td>8,738</td>
<td>1,035</td>
<td>11.3</td>
<td>Mechanical prophylaxis.</td>
</tr>
<tr>
<td>1902</td>
<td>8,719</td>
<td>846</td>
<td>19.7</td>
<td>Mechanical prophylaxis, and beginning of quinine prophylaxis.</td>
</tr>
<tr>
<td>1903</td>
<td>8,218</td>
<td>127</td>
<td>16.5</td>
<td>Mechanical and chemical prophylaxis.</td>
</tr>
<tr>
<td>1904</td>
<td>8,044</td>
<td>918</td>
<td>73.1</td>
<td>Mechanical and chemical prophylaxis.</td>
</tr>
<tr>
<td>1905</td>
<td>8,424</td>
<td>118</td>
<td>7.31</td>
<td>Mechanical and chemical prophylaxis.</td>
</tr>
<tr>
<td>1906</td>
<td>8,207</td>
<td>73</td>
<td>4.59</td>
<td>Mechanical and chemical prophylaxis.</td>
</tr>
<tr>
<td>1907</td>
<td>8,211</td>
<td>73</td>
<td>4.59</td>
<td>Mechanical and chemical prophylaxis.</td>
</tr>
</tbody>
</table>

Thus in Italy (where we have employed it from 1899), Algeria and Russia, it has been proved to be the most suitable method for guaranteeing health and the power of work to man even in the most desolate malarious regions.

On consulting Tables V and VI it appears that the mean percentage of the cases of malaria along the Ex-Adriatic railways has diminished from 69.92 to 57.9, and the mean of the days of illness from 5.48 to 3.17, owing to the gradual introduction first of the mechanical and later of the mixed prophylaxis.

Similarly, amongst the Custom-house officers the percentage of malaria has fallen from 65.30 to 4.59.3.

From all this one can conclude that by the triple alliance of the doctor, drainage and agriculture, it is possible to chase away the most formidable enemy of our country.

It is necessary, however, for the doctor to proceed with the vanguard, systematically protecting man from the fevers and
enabling him, therefore, to live and work well even in the most unhealthy places, and thus break that old vicious circle by means of which man could not live on the land because it was malarious, and it could not have been rendered healthy because man was unable to live on it.

III. Legislation Concerning Malaria

(a) Laws on State quinine.—These laws were drafted by us on a very solid experimental basis, and were introduced into our sanitary legislation as soon as their necessity and practicability were demonstrated.

The following laws were promulgated as follows:—That of 23rd December 1900 (State quinine on sale to the public at a minimum price); that of 2nd November 1901 (the right of workers of every kind to have gratuitously the State quinine for the treatment of the fevers from the communal doctors at the expense of the respective employers); that of 22nd June 1902 (concession at a low price of the State quinine to the communities, charitable institutions, and to those who desire or have to distribute it gratuitously to the workers); that of 25th February 1903, Article 3 (the right of the poor to have quinine with other drugs given them gratuitously by the communities or by the charitable institutions); and finally, that of 19th May 1904 (the right of workers of every kind to have it gratuitously also for prophylaxis).

These laws, demanded by new social duties, necessarily must have clashed with many private interests.

Parliament had the notable merit of passing them with wonderful solicitude and agreement. But even when the first law was promulgated, we saw that making it was easy enough, but that the difficulty rested in applying it. We therefore had to watch that these laws, which were the synthesis of our experience, were properly applied.

It is to be noted also that every fiscal question having been
set aside, the net profits of the great State administration (see Tables V and VII) went entirely to lessen the causes of malaria.

Further, one can loudly proclaim that our legislation on State quinine has not only a scientific, but also a moral and social purpose, inasmuch as it recognizes that malaria is a calamity connected with agricultural work; and it wisely imposes upon the employers the duty of preventing the damage by giving the preventive quinine gratuitously to the workers, and of compensating them by giving the curative quinine also gratuitously; and to the relatives of employees in public works it assures, besides, the payment of an indemnity in cases of death from the previous fevers.

In our anti-malarial legislation the mechanical prophylaxis is obligatory solely for the State employees, including the railway servants who inhabit the places where malaria is most severe. To the private persons who wish to adopt it for their dependents the State accords premiums, which are deducted from the profits of the sale of the State quinine (see Table VII).

(b) Laws regarding drainage.—Several times we have urged that our antiquated laws in drainage should be harmonised with the modern, scientific and practical views.

We have succeeded already in introducing new principles of anti-malarial hygiene as a guide in the planning and execution of these works.

Formerly it was believed that the only, or at least the best, mode of combating the fevers was sanitation by drainage; and consequently, in the supreme interests of public health, expense was no object. And, in fact, New Italy has spent or allotted upwards of 500,000 lire for this purpose, which works out at no less than 420 lire (£16, 165. 8d.) for every hectare (2.5 acres) drained. To-day, however, for less cost, namely, with good quinine and healthy houses well defended from mosquitoes, we can protect man from malaria.

¹ Compare section 57.—E. B. W.
THE CAMPAIGN AGAINST MALARIA IN ITALY

At the present day we know how to spend much better than in the past those many millions for drainage, which, if well employed, would, without doubt, render the land, at present barren and deserted, definitely prosperous and healthy.

(c) Laws on agrarian sanitation. — Our first anti-malarial campaign in the valley of the Aniene has clearly shown that reoccupation of many large areas, left uncultivated owing to malaria, can now be easily accomplished; and that the labourers can be kept healthy whilst at work by the application of modern prophylactic and curative measures.

This experiment of ours has inspired several others to adopt the sanitation of the Agro Romano, and has enabled us to encourage and direct, with the sound advice of the medical hygienist, the great undertakings of colonization arising in different parts of Italy, and destined to become economic successes.

IV.—CONTRIBUTION TO THE ORGANISATION OF THE CAMPAIGN AGAINST MALARIA

We invite, above all, the Government to set the good example of applying the new methods of the anti-malarial prophylaxis to all the workers directly and indirectly depending on it. At present the majority of those living in the midst of malaria reap the benefit of the new laws which protect them from this disease.

Also among the soldiers, sailors and carabiniers the new prophylaxis, especially the chemical, has been extending from year to year.

The benefit of the gratuitous quinine has been extending likewise among our emigrants, who depart or return suffering from malaria. To many Italians also who live outside Italy in malarial regions it has been, and is, distributed by the Ministry of Foreign Affairs, through the consuls and benefit societies; and to make it better known and appreciated, gifts of quinine
have been offered and accepted by other States which, like Italy, are fighting against malaria. Directly the above-mentioned law of 19th May 1904 was promulgated, with admirable zeal and disinterestedness our members started what are called demonstration camps for quinine prophylaxis; and we have become more and more convinced that nothing is better than these for overcoming the apathy and the prejudices of our people, who, living for ages in malarious places, if they have not proved it, will not believe it possible to protect themselves so easily, or to limit the damage which they are accustomed to suffer, and to believe comes from heaven.

We have likewise made, and continue to make, a wide propaganda of the new theories and laws concerning malaria. Of manifestoes, handbills, bulletins, reports, extracts from the laws and regulations, our Society has distributed, or helped to distribute, about 2,000,000 copies in all.

For this purpose we make use also of the National Association of Parish Doctors, the Ordini di sanitari, the Unione Medica Italiana, the Associazione dei Professori di Cattedra Ambulatori di Agricoltura, the Lega Nazionale, and the various local Leagues of peasants and miners, the Camera di Lavoro, and the medical and lay Press.

Public lectures and conversations also in dialect, repeated explanations and demonstrations, have not been neglected by our members, especially by the doctors and medical students.

Finally, we are indebted to the local anti-malarial committees which we are endeavouring to organise throughout the whole of Italy for an active propaganda by means of facts, publications, lectures, etc.

V.—GENERAL RESULTS

The following figures enable us to believe and hope that our labours have not been in vain:—
From the foregoing table it appears that the annual consumption of State quinine has progressively increased from 2,242 to about 23,000-24,000 kilograms, and that in these seven years the mortality from malaria has progressively diminished four-fifths.

This intimate relation between the progressive increase of one and the progressive diminution of the other cannot honestly be ignored or denied.

In fact, from 1887 to the end of 1895 upwards of 15,000 persons died annually from malaria. From 1896 to 1902 an attenuation began (see fig. 1), but still 13,000 ill died annually, a mortality which was much augmented by that of the period of the recrudescence in 1900. On the contrary, owing to the introduction and the continuously increasing diffusion of the State quinine, the mortality from year to year has rapidly
fallen to less than 4000 victims, and the characteristic periodic
recurrences have no longer prevailed themselves.

Now, who can deny to-day that quinine is not the sovereign
remedy, and that only those die from malaria who do not
take it in time and in sufficient quantity? This was, and
undoubtedly is, one of the principal causes of the very high
mortality in the poorest regions of Italy, because they are the
most malarias, and they are the most malarias because
they are the poorest.

Well, the lowered mortality from malaria in these regions
— see fig. 2 — proves to us that the sovereign remedy is used more
and more among the poorest, and thus our legislation has begun
to attack this high social aim, namely, to break that old vicious
circle of poverty and malaria. If one considers, besides, that
in the above period the importation of quinine into Italy by
private means remained more or less the same (see fig. 3, middle
part), consequently the consumption of the "private" quinine
has not diminished, while that of the State now equals it, and
thus the total consumption of quinine is almost doubled (see
fig. 3, middle and lower parts).

Regarding the efficacy of sanitation by drainage, which
necessarily proceeds very slowly, there is little to hope. Also
to the spontaneous diminution of the epidemics, one can only
assign that value which, according to fig. 3, must be cal-
culated on the basis of the preceding years.

It is certain that, owing to the State quinine, which is now
free at the disposition of all, no person ought to die from
malaria, and many fewer persons ought to contract it.

We remember, however, that from the Marittima downwards,
including the Messineo and the islands, very severe malaria
has reigned undisputed for centuries; and during the five years
that our special legislation has been in vigor, and in spite of
the efforts of the administrative powers, there are still many
communes which do not furnish quinine in sufficient quantities,
not even for the treatment of the fevers; and for prophylaxis very few workers receive it regularly and sufficiently.

We are, however, at the dawn of the redemption of Italy from this scourge, and in these years of study and struggle1 our Society, one can say without boasting, has hoped to indicate a relatively easy path to the desired goal, and has removed some of the many obstacles to success.

Be this as it may, after having taken a notable part in the international researches into the cause and propagation of malaria; after having studied its epidemic, improved the methods for combating it, and introduced new ones; enriched the patrimony of the pathological knowledge; prepared new laws and endeavoured to improve the old ones; defended the new theories and laws in order to make them more readily enter into the customs of the people, and enlarged the sphere of action for all Italy, we have the serene consciousness of having performed a useful duty towards our country. And we cannot but be delighted that outside Italy, and following our example, other attempts are being carried out, that anti-malarial campaigns are being initiated, and that other societies or leagues similar to ours have been formed in Algiers, Corsica, Greece and Russia, while scientists of all nations visit and appreciate our work. Besides, our anti-malarial legislation has not only been imitated by Austria, and by France for Corsica and Algiers, but has also been wholly adopted by Portugal, Greece, Bulgaria, Argentina. . . . All this enables us to foresee the formation of an international alliance against this universal epidemic, as has been formed already against other epidemics.

1 From 1893 to July 1909, we had at disposal for our work only about 90,000 lire.

2 On the unanimous proposal of the reporters Ross, Rugge, Galli-Valerio, Savas, and Celia, section vi. of the Fourteenth International Congress of Hygiene and Demography adopted by acclamation the following resolutions:

"The Hygienic Congress urges upon Governments of malarious countries a more active campaign against malaria by means of all the methods proposed by the reporters to the Congress on this subject, and particularly if follows:

"1.) The sale by Governments of good and cheap quinine on the basis of the Italian law.

"2.) The appointment of special medical commissioners by the Governments of
VI.—CONCLUSIONS

The campaign against malaria should be conducted, two measures acting concurrently:

(A) The one directed (a) to destroy, or at least (b) render inoffensive, the mosquitos which inoculate man with the parasite.

(B) The other directed to destroy (a) with specific means, (b) with general means, these parasites in the human blood.

(A—B) The extinction of mosquitos can be obtained by physical, chemical and biological means. Frequently, however, in the open country, the extinction is interfered with by the extent to which the reproduction of these insects is assured in Nature; and while, therefore, it requires money and organisation, it can have practical application only in limited districts, and assisted, where possible, by better and more extensive drainage.

On the other hand, sanitation by drainage, while it also requires time and money, which falls in getting rid of all the surface water or in putting it in movement, does not succeed in removing the local conditions necessary to the life of the mosquitos, and even when it can succeed agriculture is frequently opposed to it, as in warm climates the surface water is utilised for the cultivation of rice, etc. Hence it is that sanitation by drainage by itself alone is not always efficacious in eradicating malaria from extensive territories.

(A—B) It is relatively more easy in definite circumstances to render the mosquitos inoffensive, even in the most dangerous seasons and places, by keeping them away from persons and houses with both chemical and mechanical means (mechanical prophylaxis).

Be this as it may, when one desires to, and can adopt any means whatever directed against the mosquitos, one must never disregard malaria countries to devise any suitable means and to superintend the collection of the malaria statistics for those countries.
forget that in many parts of the world the Anophelus are always present, and nevertheless malaria either has disappeared or has become, or tends to become, attenuated. (B) The destruction of the malarial parasites in the human blood, as is well known, can be obtained by means of the specific remedy, quinine.

However, it is certain that this acts in inverse proportion to the stage of development of the parasites, and hence it is that the forms destined to assure the conservation and propagation of the species resist most, and that instead the sporozoites resist slightly. Therefore, more easily and more readily than with the curative use, one obtains the specific internal disinfection by means of the preventive use of quinine, and of its preparations soluble or not in water, administered in the most agreeable form, and preferably in average doses daily (40 centigrams per die), or in days very near one another, in order to establish a perfect mithridatism.

With this preventive treatment extended in the epidemic period to the greatest possible number of inhabitants of a malarious zone, and with in every season the most incessant and prolonged quinine treatment of the malarial patients, one will see the primary infections immediately reducing themselves to the minimum, the recurrences reducing themselves much, and the pernicious cases and the cachexia disappearing, and thus from year to year the diminution of the epidemic among the respective populations will become more manifest even where the paludal and the local anophelic state remains. But to reach all this on a large scale it is indispensable that the State itself should manufacture the quinine preparations in order to sell them at the minimum price or to distribute them gratuitously, and always in the more agreeable form (candies or chocolates, etc.).

Hygienic education, with the continuous popular propaganda and anti-malarial sanitary organisation, will do the rest. Especially, then, with the quinine prophylaxis (eventually coupled with the mechanical) one can immediately, where and
when one desires it, keep man healthy even on very unhealthy land, and thus render possible, or at least more easy and prompt, the drainage and agricultural works necessary for the definite sanitation of even very vast districts.

Thus more promptly and without the mortality of earlier times we can arrive today at the agro-sanitation, and colonization of malarious districts, or establish those general means, namely, improving the alimentation, clothing, housing, education of man, which in every period of civilization augments the organic resistance against the malarial parasites, and by this means more easily subdue malaria, even in the places where anophelism may not become extinct.

Evidently neither of the above-mentioned series of measures for combating malaria exclude one another, but can mutually help one another, and ought to be adopted together in practice.
50. Anti-Malaria Measures in Greece.—Greece is one of those countries which are very severely scourged by malaria. The information, collected by the Anti-Malaria League from all the mayors of the kingdom, and from a great number of physicians, proves that the average number of cases of the disease throughout the kingdom is 29, or, in other words, out of a total population of 2,631,952 inhabitants, an average of 770,000 are affected by the disease every year. It happens, however, that in some years the number of cases is far heavier. Thus, for example, according to the statistics of the League, in the year 1905 more than half the inhabitants of the country were affected by malaria, and over 6,000 died of the disease.

Of the 69 provinces of the kingdom, 19 show a number of cases equal to or over 40% of the number of inhabitants, and of 445 communes only 22 are free from the disease, whilst the remainder are affected in a greater or smaller degree, especially in the cases of 59 communes with a percentage of 41 to 50%, 33 with 51 to 60%, 23 with 61 to 70%, 18 with 71 to 80%, and 2 with 81 to 90%; or 135 communes (nearly one-third of the total number) with a percentage of over 40%. In years of epidemic it happens that in many communes the whole of the inhabitants are attacked by malaria.

The cause of this great frequency of malaria is not only climatological, but is also due to the existence throughout the
country of numerous marshes and torrent beds. According to the information collected at my request by the Government, there are in Greece 639 marshes, each of an area above one stremma (1,000 square metres), which cover together from 84,657 to 87,903 hectares, or 846.879 square kilometres. As the whole kingdom of Greece covers an area of 609,000 square kilometres, these marshes occupy an extent varying between 1/68 and 1/77 of the whole surface of the kingdom. In addition to these marshes Greece is full of small marshes of under 1,000 square metres in extent, and of torrent beds which owe their existence to the widely-spread deforestation of the mountains, due to repeated forest fires during the long period of Turkish domination, as well as during the Seven Years' War of Independence. These torrent beds are full of small pools which are pre-eminent nurseries of Anophelines, and consequently the chief cause of malaria in Greece.

Malaria is at its height in Greece during the months of July, August and September, and commences to decline in October and November; but relapses continue throughout the winter (from December to March), and with the first heat of May the disease recommences its baleful activity.

Malaria has from prehistoric times been the scourge of Greece. The classical description of the disease in the works of Hippocrates is well known. Information concerning malaria during the decline of ancient Greece is lacking, and it is only after the birth of modern Greece that descriptions of the spread of the disease again appear. Notwithstanding the fact that these descriptions are short and rare, it is to be gathered therefrom that the disease was widely prevalent, especially at the commencement of the establishment of the new state, when the cultivation of the land had not made much progress. However, after the reinstatement of law and order the population increased, villages and towns sprang up, the cultivation of the land spread more and more, and measures began to be taken with the object of draining many of the smaller and some of
the large marshes, and of regulating the beds of the torrents.

By these measures, and at the same time by the application
of more careful medical treatment and the wider use of quinine,
malaria commenced to decline, and there is no doubt that the
disease is now not only less common, but also less virulent than
formerly.

This relative amelioration is not, however, due to a
systematic campaign against this disease, but to the above-
mentioned causes which came about in so to say, automatically
with the progress of civilization. The methodical and systematic
fighting of malaria only commenced when, in January 1905,
I founded the Anti-Malarial League, which laid the first
scientific and practical basis of the campaign against malaria,
and met with an extremely favorable reception in all parts
of the country. We propose hereinafter to give a concise
description of the general measures which have been taken
by the Government and by the League, as well as of the
special sanitary operations which have been executed either
by the Government or by the League or by different com-
panies.

The general measures include the popularization of the
ideas now prevalent regarding the manners in which malaria
is caused and repressed, and the undertaking of the supply
and sale of quinine by the Government.

11

Propaganda of scientific knowledge concerning malaria.—
Two years previous to the foundation of the League I issued
a pamphlet, Instructions for Use in Combating Malaria, which
was printed at the cost of the Government and distributed in
thousands amongst all the physicians, engineers and mayors
of the kingdom. On the establishment of the League, one
of its first cares was the publication of a small pamphlet of
32 pages containing short instructions regarding the
causes and prevention of malaria. Forty-five thousand of these pamphlets have been distributed amongst not only all the local authorities, but also many of the educated inhabitants, especially the schoolmasters, who have been instructed by the Ministry to explain the question to their pupils. Last year, too, the Government printed 10000 copies of a leaflet containing the details of malaria. The leaflet was distributed amongst the pupils of the schools, who, after the teachers had explained the instructions to them, were told to give them to their parents. At the same time of late the daily press and the periodicals of the whole country kept repeatedly published illustrated articles on the part of members of the League respecting the causes and prevention of malaria. In addition, some hundreds of the leading physicians of the country were invited to Athens by the League. These gentlemen remained for two days in Athens, and consulted with the chief members of the League regarding the ways and means of combating malaria in Greece, and heard us explaining the latest scientific discoveries in this connection. On their return to their homes they acted as apostles of the anti-malaria movement, which amongst the other local medical men, the authorities, and the people, visiting the chief malariaous districts of the country, and both pointing out the absolute need of the preventive use of quinine, searching out the small pools which serve as nurseries of Anopheles, and applying, wherever possible, the various sanitary measures recommended in the work of Professor Ronald Ross, "Mosquito Brigades," which has been translated into Greek and printed at Government expense and distributed gratis.

The importance of combating malaria and the manner of so doing have repeatedly been explained to the engineers and heads of the Agricultural Schools, and especially to schoolmasters, whenever they have been assembled for educational purposes by the Government inspectors.

The League has also approached the rich landowners,
furnishing them with printed instructions and pointing out the necessary sanitary measures in connection with the pool on their estates, and urging them to disseminate and apply general measures for the prevention of malaria.

Conjointly with measures for the popularisation of the methods of combating malaria, the League has also attended to the collection of local information concerning the disease. Official Health Statistics are issued in Greece only in the case of the twelve chief towns of the kingdom, the population of which altogether amounts to 433,000, and they are confined to the number of deaths, whilst with regard to the frequency of disease and the mortality in the rest of the kingdom no official statistics are to be had. We have consequently deemed it right to apply for information to all the physicians of the country regarding the number of cases of malaria in the districts in which they practice. This information refers to the periods of the commencement, the height and the decline of the disease to the ascertainmment of the percentage of cases among the inhabitants, both absolute and relative to past years, and to certain other questions. We succeeded in collecting information of this kind relating to five years. Several of the physicians drew up at the same time lengthy reports containing malaria in their provinces, and respecting the marshes in the district, with the measures by which the disease may be stamped out. At the request of the League the Government instructed all the local mayors to submit reports as to the number of cases in each commune, and the marshes existing therein. A complete epidemiological chart of the frequency of the malaria in Greece was thus drawn up. This plentiful material was published by the League in three bulky volumes, which also contain the results of a similar work undertaken in the island of Crete by our League. We are of the opinion that the collection of information of this kind is not merely valuable for the sake of the information itself, but also in that it incites physicians, mayors, engineers and people generally...
soJ STATE QUININE 437

speaking to turn their attention to the spread of the disease and the detriment caused thereby, keeps them in continual intercourse with us and the question always on the Ague, undoubtedly resulting in measures being taken with a view to combat the disease.

111

The State Quinine.—In view of the splendid results achieved in Italy by the introduction by the Government of the provision and sale of quinine, the League has recommended a similar measure for Greece. We were also induced to take this view by the fact that considerable abuse took place in connection with the sale of quinine, which is sold in Greece not only by chemists but also by grocers. This quinine not only is sometimes of bad quality but is often adulterated with foreign substances, besides which it is far from being sold underweight to customers, whilst, to crown all, it is sold at a very high price, so as to render the frequent use of quinine by the poorer classes beyond their means. As a means of putting a stop to these abuses the League appealed to the Government and the Chamber, writing forth the harm done by malaria, and at the same time pointing out the means of remediating the evil, the foremost of which is considered to be the underwriting by the Government of the provision and sale of quinine. At the same time the League published the report, which was sent at our request by the Liverpool Tropical School, followed by a draft of a bill concerning quinine, together with an explanatory report, and finally a translation of the Italian laws regarding the combating of malaria.

The Chamber refused to accept the principle of a monopoly of quinine proposed by the League, and on the 15th of December 1907 passed a bill similar to the Italian quinine law. According to this the Government acquires the right to order and to sell any of the salts of quinine recommended
by the Royal Sanitary Council. The order is given by the Minister of Finance on the basis of tenders (except in case the quinine is purchased from foreign State institutions), and fixed upon on each occasion by the Sanitary Council. The sale of quinine is made by the Chemical Laboratory attached to the Ministry of Finance, by the Public Treasuries, post and telegraph offices, educational functionaries, and by other authorities chosen by Royal Decree. The State sells quinine at cost price. It is sold retail to the public by chemists, govern and other merchants, who derive a small profit therefrom. In the case of bisulphate of quinine the law demands that the retail price per gramme shall not exceed 10 lepta centimes. The price of other salts of quinine is fixed, as occasion arises, by Royal Decree. The importation and sale of quinine is not prohibited by this law, but such commercial quinine will be examined chemically at the custom houses and will only be allowed to enter provided the quality is equal or superior to that of the State. Heavy penalties are prescribed for persons selling State quinine or the commercial article at prices above that fixed; adulterating or selling adulterated quinine smuggling quinine into the kingdom or selling quinine underweight. The law also obliges such remainees as are severely assaulted by malaria to enter in their budget an amount destined for the purchase of State quinine to be distributed gratis to the poor of the commune.

After the publication of this law Greece requested the Italian Government to supply the requisite amount of quinine out of that prepared for the latter. The Italian Government was kind enough to consent, and the Greek Government now receives from Italy bisulphate and hydrochlorate of quinine in tablets of 0.20 gramme, packed in boxes containing ten glass tubes, each of five tablets. The contents of the box, together with the price and the above-mentioned penalties, are printed on the outside label. The glass tubes are wrapped in paper containing full instructions for the use of the quinine, in which,
STATE QUININE

in the case of adults, the dose prescribed is five tablets (1 gramme) per day for a week, followed by two tablets per day during the following two months. The inhabitants of marshy districts are recommended as a preventive measure to take two tablets every day from the end of May to the beginning of November. The proper dose for children is also given in these instructions. Besides these tablets, the Italian Government supplied phials for hypodermic injections containing a solution of quinine made up according to the prescription of Galli (1 gramme solution contain 0.40 hydrochlorate of quinine and 0.20 ethyl urethane). These injections have an alkaline reaction, and are painless, whilst they cause neither nausea nor sickness, and are very easily absorbed. We were also supplied with tablets of tannate of quinine, each double chocolate containing 0.05 gramme of tannate of quinine, or 0.01 gramme of pure anhydrous quinine (dry-castatin).

This State quinine, which is sold, not only by chemists, but also by merchants of every kind, found its way with astonishing rapidity all over the kingdom. Ten thousand kilogrammes of quinine in tablets and 60,000 boxes of chocolates were sold in the first year after its introduction, which ended in September last. This is a large quantity if it be remembered that the average sale of quinine by merchants during the previous seven years amounted to 6,000 kilogrammes, and that besides this State quinine, a further amount of quinine derived from other sources was sold by retailers. The quantity thus sold is not yet known to us.

The League has especially endeavoured, by means of various publications and by circulars addressed to physicians, to promote as much as possible the preventive use of quinine. We are, however, afraid that the achievement of this object will be difficult, as the majority of people will only take quinine after being attacked by malaria.

We have now given a description of the general measures
employed against malaria, and shall next describe a few of the sanitary measures undertaken in certain districts of the country.

IV

Anti-malaria measures in the plain of Marathon. — After endeavouring by every means to popularise the knowledge of the mode of fighting malaria, the League considered it to be its duty to provide a practical example, by undertaking at least one definite work of the kind, with the object of convincing people of the efficacy of the measures recommended. It was also necessary for the conditions, which are indispensable for the achievement of such work in Greece, to be studied on the spot. With this object in view Marathon was chosen as the field of action.

The plain of Marathon lies on the east coast of Attica, at a distance of 30 kilometres from Athens, and is 11 kilometres in length. It is famous in connection with the battle fought in 490 B.C. between the Greeks and Persians, and contains a few villages, amongst which is that of Marathon, the capital of the commune. The northern part of the plain is traversed by a torrent which runs close to the villages of Marathon and Bey, whilst at the north-east extremity of the plain there are extensive marshes. The following villages and hamlets are situated in this plain:—the village of Marathon with 1,200 inhabitants; that of Bey with 150 inhabitants, at a distance of 1 kilometre from Marathon; that of Lower Souli with 100 inhabitants, at a distance of 3 kilometres; besides these, eight hamlets are scattered over the plain, with 173 inhabitants in all. The total population of the plain thus amounts to some 1,580 souls, most of whom are engaged in agriculture and vine-growing, and a few in poultry and stock farming, and thus spend the greater part of their time in the
plain, returning to their houses to spend the night, with a very few exceptions.

The inhabitants of the plain of Marathon are extremely subject to malaria. An examination, conducted in October 1906, of the patients of the local school, showed that 82% suffered from an enlarged spleen. In May 1907, 2,126 persons were examined, and 1,771, or 83.7%, suffered from fever during the previous summer. These observations coincide with the reports of the Marathon doctors, one of whom put the number of cases of malaria in 1906 at 97, and the other at 87. Owing to the great prevalence of malaria the inhabitants, at the commencement of our work of sanitation, were pale and yellow, and their skin dried up, whilst they appeared exhausted and incapable of work owing to frequent attacks of fever. In many cases the spleen was extremely, and reached the pubic symphysis. According to the evidence of the local physician the mortality was very great, not merely among the children, but also among adults, whilst death occurred not only from pernicious fevers, but to a great extent from pneumonia, which is one of the commonest diseases of the place. Mortality was so common amongst adults that three-fifths of the inhabitants had been married a second time, whilst persons of over sixty years of age were rarely found; whereas longevity is common in the healthy villages of Greece.

Throughout the whole plain of Marathon stagnant waters were found in the bed of the torrent, which flows near the two villages, in the two large marshes, and in small pools between the two marshes.

In this stagnant water we invariably found larvae of Anopheles mangrovi. Both in the bed of the torrent and the basin of the villages of Marathon and Bey the Anopheles superplicatus was especially noticeable, whilst in the marsh of Lower Souli a large number of larvae of Anopheles claviger was found, together with a small number of Aedes aegypti.
in the houses of this village a large number of *Anopheles claviger* was remarked. In the other marsh, which is situated at some distance from the villages, repeated examination brought to light a very small number of the larvae of *Anopheles superpictus* and *claviger*. In all the other distant pools throughout the plain only *Anopheles claviger* was discovered, but in large quantities. The chief source of the malaria in the villages of Marathon and Iby was therefore concluded to be the adjacent forest and that of the village of Lower Souli, the neighbouring marsh. The inhabitants of the hamlets in the plain were, of course, infected by mosquitoes from the other pools.

The first larvae of *Anopheles* were remarked, in the case of the year 1907, at the end of April, and in 1908 at the commencement of May.

The work of sanitation was carried on at Marathon during three successive years, and only during the summer and the commencement of the autumn. In the year 1907 we commenced on 1st May and continued until November, whilst in 1908 and 1909 we carried on operations from 1st June to 20th October. The staff engaged in this work was composed in 1907 of one physician and one medical student as assistant, both despatched from Athens for the purpose, whilst in 1908 we employed one physician and two medical students, and in 1909 only one physician without any assistant. The physician and his assistants were installed in a small house in the village of Marathon, where they set up a microscopic laboratory, and a pharmacy which included a certain number of absolutely indispensable drugs besides quinine. Patients received advice and treatment gratis. Only sufferers from malarial diseases were admitted, all other applicants being referred to the village physician.

The work was performed in the following manner—in the first place, the names of the inhabitants of the villages were entered in a special register, together with their age, and any enlargement of the spleen stated, as well as, in many cases
the result of the microscopical examination of their blood.
The inhabitants were next divided into as many sections as there were physicians of the League, and each of these doctors took care of the inhabitants who fell in his section. Patients complaining of attacks of malaria were examined as regards both their spleens and blood, and if proved to be so suffering, were subjected to the proper treatment as described below.

As a means of facilitating our work several lectures were given by our physicians to the people, and by the teachers to their pupils, explaining the plan of the League to render healthy the plain of Marathon, and other related details. At the commencement of our work the peasants showed some distrust. Later on, however, when they were convinced of our good intentions, they willingly agreed to undergo the treatment proposed by us, and showed considerable gratitude at being liberated from the terrible scourge which had from time immemorial tormented their country. We proceeded in the work of sanitation, firstly by destroying the larvae in the torrent bed, and secondly, by administering quinine, which was purposely distributed in a different manner in each of the three years. In order to prevent the development of Anophelines in the torrent bed the water thereof was drawn off in a narrow channel so as to produce a more rapid flow, whilst all pools were treated every ten days with petroleum, which generally is provided by the Government, mixed with tar, at a minimum price for the purpose of destroying locusts. In this part of our work we received valuable aid from the teacher of the village, who indefatigably attended to the carrying out of this measure with the help of his young pupils.

The quinine was given therapeutically throughout the three years, and preventively only during the first and the second year. Sulphate and hydrochlorate of quinine were given therapeutically to patients of ten years of age at the rate of 0.015 grammes per diem for eight successive days, in the case of those who had suffered one or more attacks, or in whose blood
parasites were detected. Children under ten were treated therapeutically with a quantity of quinine proportionate to their age, i.e., from eight to ten years of age, 0.05 grammes, from six to eight, 0.06, and from four to six, 0.04 gramme.

Children under four were given tannate of quinine either in powder or in chocolate; during the first year the sulphate or hydrochloride of quinine was given in water, and during the two remaining years in the shape of tablets.

In addition to the therapeutic employment of quinine during the first year we also used the drug preventively. With this object we gave out quinine to all the inhabitants, irrespective of whether they suffered from fever or not, according to the method of Koch as modified by the Italians, i.e., 0.1 grammes of quinine per diem for two successive days in the week to those above the age of ten, and a proportionate quantity to the children, i.e., 0.073 grammes in the case of those aged from eight to ten, 0.05 in the case of those aged six to eight, and 0.02 grammes to those of four to six. In the case of infants below the age of four they were given eucaprine or chocolate with tannate of quinine. The quinine was given out to the pupils every Thursday and Friday at the school, and every Saturday and Sunday to the other preserves. It must, however, be contradicted that this preventive method did not prove to be practically applicable, as the peasants, healthy men in other respects, who worked on week-days in the fields found such large doses very annoying, owing to the consequent singing in the ears and other discomfort, especially on Sundays, the only day in the week on which they can rest and amuse themselves. These large doses also hindered them in their work during the week. Several of the pupils suffered so much from giddiness and drowsiness after taking quinine that they were unable to attend to their lessons.

Out of the 1,680 inhabitants only 1,542 went through this preventive treatment in 1,252 cases. Unfortunately, all would not continue a regular course, but the figures given hereunder
RESULTS

show the results of the preventative treatment according to the length of application.

Of 67 persons who took quinine during 21-24 weeks none were attacked by malarial fever.

Of 145 persons who took quinine during 25-30 weeks 35 were attacked, or 24.3.

Of 220 persons who took quinine during 31-36 weeks 103 were attacked, or 46.8.

Of 85 persons who took quinine irregularly during 1-10 weeks 40 were attacked, or 47.1.

It follows, therefore, that out of 1,752 persons taking quinine only 57, or 3.21, suffered from malaria. It must here be added that in the surrounding villages, which were not included in our sphere of action, malaria was prevalent to a very great extent, so that we may consequently consider that, without our intervention, we should have had the usual number of cases of malaria at Montebello, or from 90 to 100 cases more.

An investigation carried out in May 1907 showed 57 out of 125 pupils of either sex, and of 303 out of 712 adult inhabitants. After the conclusion of the sanitary work, or at the end of October, an examination of 110 persons showed only 35 with enlarged spleen, and of 593 whites, 23.7.

The proportion of cases of enlarged spleen was therefore less at the end of the summer season, thanks to the sanitary measures, without which, it would have been greater.

In the whole district under our control one person died of pernicious fever and three persons of blackwater fever. All three were treated by the local physicians. In 1906, according to information furnished by the doctors, seven persons died of malarial diseases.

During the summer of 1908 we changed the manner of giving out quinine, and adopted the Italian preventive system, i.e., between 1st June and 30th October we gave out every day two tablets (0.40 gramme) in the case of persons above the age of ten, and one only 0.20 gramme, in that of children below
the age of ten down to the age when swallowing the tablets was not possible. In the case of infants unable to swallow the tablets we gave chocolate with tannate of quinine, as furnished by the Italian Government. As, however, we only had a small stock of these, we confined their use to the cases of twenty-six infants, and for a short period only. It may therefore be said that the preventive method was not applied in the case of infants of under three years.

Out of 3,394 inhabitants of the villages of Marathon and Hy menes only sixty (?283) suffered from malaria during the whole summer. If, however, we deduct from these two pregnant women, who took no quinine from fear of causing a miscarriage, twenty-one children, who only took quinine irregularly owing to the lack of "exquisition" one who came infected from Athens, one who suffered from urticaria owing to the use of quinine, and one of the local doctors, who refused to undergo the preventive treatment together with four persons who were infected at the commencement of our work, there remain forty-six cases of malaria, and the percentage is reduced to 1.29.

It is to be remarked that in the surrounding villages the malaria was very severe.

There died only one child of those who regularly took quinine, of a disease which the local doctor who was attending it described as permicious fever, without, however, parasites being discovered in either of two examinations which were made of the blood.

With regard to the examination of the spleen of the pupils this showed an enlarged organ in 31 to 41. at the beginning of June, and 40 to 45 at the end of October.

This method of giving out quinine was welcomed by the inhabitants, who both remarked the beneficial results and experienced no ill-effects, and showed great willingness in adopting it.

During the third and last year of our work at Marathon (the summer of 1903), we neither took measures against the
larvae of the Anopheles, neither did we give out quinine for preventive treatment, but confined ourselves to the therapeutic employment of the drug according to the Austrian treatment adopted in Dalmatia. We therefore gave out quinine only to those who had suffered distinct attacks of malaria, and whose blood contained the parasite. The quinine was given out in the following way:-one gramme of State quinine every day for a week, followed by 0.20 gramme every day for two months, in patients of the age of ten years and above. In the case of children from eight to ten years of age, 0.10 gramme every day, from six to eight, 0.05 gramme, from four to six, 0.05 gramme in each case for a week, followed by 0.10 gramme every day for two months. In the case of children below the age of four years State chocolate with tannate of quinine was given. The result of this treatment was that out of the 1,312 inhabitants only 346, or 26.7%, suffered from malarial attacks, detected by microscopic examination of the blood. The fifteen infants which were treated therapeutically with chocolate only suffered a single attack in each case.

Examination of the spleen after the termination of the sanitary work showed enlargement in 14.4%, while at the commencement of January it amounted to 25.7%.

During the whole summer two children died of malignant fever, according to the diagnosis of the local doctors, which, however, was conducted without a microscopic examination of the blood.

The quantity of quinine expended in these three sanitary campaigns at Marathon amounted to an average of 150 grammes for each inhabitant in 1907, 323 grammes in 1908, and 189 grammes in 1909.

The total expense during 1908 reached Drachma (= Franc) 5,713—or an average of Drs. 43.70 for each patient undergoing the preventive treatment. In 1908 the amount expended reached Drs. 627.60—or Drs. 5.14 per head; whilst in the year

including pay of the medical men.
We gather the following conclusions from our three years' work at Marathon. The Koch preventive method seems likely to meet with considerable difficulties in our country; that of Celli, in combination with the destruction of the larvae of the Anophelus, gives excellent results, and is an ideal method of combating malaria. Nevertheless, that method is not easily applicable in every part of the country, as it requires continual supervision of an expert in order to oblige the inhabitants to continue taking quinine every day during the whole summer, and for a series of years, until a permanent cure is effected. It can, however, be employed with excellent results in the army and the navy, in the prisons, railway and other companies, in mines, in villages forming private property, and, generally speaking, everywhere where there is a single authority, with the power of enforcing that method willy-nilly upon those under it. Throughout the rest of the country, however, which is inhabited by independent people, who regulate at will their life and diet, it is difficult for the Italian method to be introduced. Those, however, who have suffered from fever and have taken quinine at irregular intervals without being able to throw off the disease, will be gladly surprised to see the favourable results which are produced by the medical use of quinine such as applied by us at Marathon during the third year of our work, and so recovering their shaken faith in the drug, they will most probably end by adopting the Italian preventive method.

Sanitary work at Laurium.—A work of a similar nature was undertaken during the summer of 1909 by the Greek Laurium Mines Company, the employees of which suffer excessively every summer and autumn from malaria. This work
was confined to the preventive treatment with quinine, as in excavating the mines numerous large hollows are formed in the soil, and these being filled with water and serving as reservoirs of *Anopheles*, it becomes impossible, owing to their large extent, to destroy the larvae. Every miner was provided with two tablets (0.40 gram) of State quinine per day from the commencement of May to the end of October. The result of this treatment was that out of 480 miners only 28 (5.8%) were attacked by malaria, whereas in each of the foregoing years, 1904-1906, from 30 to 40% suffered from fever. That this good result is due to the use of quinine may be seen from the fact that, of 72 miners who failed to take quinine regularly, 34 were attacked by malaria.

VI

Sanitary work in Athens.—In the city of Athens the two suburbs which suffer most severely from malaria are those of Panepigoni and Pireas, where, before the year 1900, the percentage of cases fluctuated between 25 and 30%, and from 1901-1906 it reached 40%, and even as high as 50%, as will be seen in the following table. This excessive prevalence of malaria was due to the small pools in the bed of the river Ilios, which were found to be full of larvae of *Anopheles superpictus*.

As a means of coping with this situation, the League requested the Government to undertake certain sanitary works in the bed of the Ilios, and, as a matter of fact, in the summer of 1906 the Government carried out the work in question, which consisted chiefly in levelling the inequalities in the river-bed, and in drawing off the water by means of a narrow channel where the development of *Anopheles* was hindered by the rapid flow of the water. In 1906 the work was but slowly conducted, and consequently the influence upon malaria was slight, as shown by the table given below.
the second year, 1907, the percentage of cases of malaria in the Pankrati fell to 2 or 3%, and in the Batraconevi, where the work was carried out later in the season, it fluctuated between 25 and 30%. In the summer of 1908 the work of sanitation commenced at the proper time in the Ilissos, and as a result the number of cases of malaria fell to 1%. In 1909 the work was also carried out in due time and the cases fell to 0.66%. It is to be remarked that no preventive use of quinine was resorted to, and so the satisfactory results are entirely due to the work carried out in the bed of the Ilissos.

**Comparative Table of the Cases of Malaria Among the Children in the Pankrati and Batraconevi Suburbs**

**Before the adoption of the sanitary measures (Pezopoulos and Cardamomos)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1901</td>
<td>250</td>
<td>100</td>
</tr>
<tr>
<td>1902</td>
<td>200</td>
<td>160</td>
</tr>
<tr>
<td>1903</td>
<td>135</td>
<td>192</td>
</tr>
<tr>
<td>1904</td>
<td>100</td>
<td>89</td>
</tr>
<tr>
<td>1905</td>
<td>200</td>
<td>181</td>
</tr>
</tbody>
</table>

During the five years the percentage was 28.6%.

**After the adoption of the sanitary measures (Cardamomos)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906</td>
<td>301</td>
<td>177</td>
</tr>
<tr>
<td>1907</td>
<td>345</td>
<td>73</td>
</tr>
<tr>
<td>1908</td>
<td>300</td>
<td>82</td>
</tr>
<tr>
<td>1909</td>
<td>300</td>
<td>0.66</td>
</tr>
</tbody>
</table>

During the same period the percentage was 21.2%.
By Prof. Claus Schilling
Late Medical Officer of the German Colonial Office, at Togo, West Africa
Abteilungsleiter im Institute für Infektionskrankheiten, Berlin.

51. The Prevention of Malaria in German Possessions—

When Germany began colonising, she found herself face to face with the problem of developing the raw material of the territories she had occupied, making it accessible to trade and civilisation.

The development arrived at in these twenty-six years has not been such as to render the colonies able to dispense with the support of the mother-country. The empire has also to make it her care to improve the health conditions of those under her protection. But the science of Hygiene is able to obtain only by slow degrees the place due to it in the work of colonisation, conducted on economical principles. It requires the greatest energy on the part of the doctors to obtain what is necessary from the very slender means at the disposal of the authorities.

Of the tropical colonies of Germany—viz.: East Africa, Kamerun, Togo, and the north of South-west Africa, New Guinea, the Carolines, and Samoas in the South Seas—only the two last-named are free from malaria; in all the others it is, next to small-pox, the most widespread of diseases. The following summary gives information as to the frequency of malaria amongst the natives.
It is evident from this table, amongst other things, that the development of immunity in malarial districts is by no means of equal extent. It is evidently connected with the frequency of infection by stings from infected Anophelines. In spots where no decided alternation between the rainy and the dry season takes place (e.g., New Guinea) there is also constant opportunity for fresh infection and for re-infection. This point is to be taken into consideration in a plan of malaria prophylaxis. The table is so far of interest as showing that active immunity in malaria by no means sets in with certainty (e.g., in Duala, only in 50% of the natives who had been exposed at least for ten years to the infection without a break). The chances, therefore, of acquiring active immunity fluctuate between 13:1 and 1:1 during a sojourn of from ten to fifteen years in dangerous malarial districts. The practical unimportance of the objection, that malaria prophylaxis interrupts this active immunity, may be considered as proved by this computation.

<table>
<thead>
<tr>
<th>Region</th>
<th>Active Immunity</th>
<th>Passive Immunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Guinea</td>
<td>38%</td>
<td>50%</td>
</tr>
<tr>
<td>Eye-Guiana</td>
<td>45%</td>
<td>50%</td>
</tr>
<tr>
<td>Bongo</td>
<td>38%</td>
<td>35%</td>
</tr>
<tr>
<td>Koch</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>Wolf</td>
<td>45%</td>
<td>50%</td>
</tr>
<tr>
<td>Tanga</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>Dar-es-Salaam</td>
<td>38%</td>
<td>45%</td>
</tr>
<tr>
<td>Kamerun</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>Togo</td>
<td>40%</td>
<td>45%</td>
</tr>
</tbody>
</table>

* The percentage of those examined found to contain parasites.
Diagrams 1 and 2 show a comparison of the value of microscopic examination of the blood and palpation of the spleen. They show that in Tanga, East Africa, the two curves of the spleen rate and the positive results of blood examination correspond approximately, so that the latter could replace the former. But in Anacho it was only in children between two
and five years' old, that palpation of the spleen produced higher results than examination of the blood; whereas in later years the spleen tumour quickly subsides, even where malarial infection exists. So that if the spleen tumour is to be made use of as an indicator of the malarial index of some special locality, the relation between spleen tumour and condition of the blood must be first of all ascertained by comparative examination, which must then be taken into consideration in the computation.

To introduce individual therapeutics only on the basis of spleen palpation is not feasible, according to Panst's and my own examinations. Panst, for instance, found that in a positive condition of the blood the spleen tumour was absent,
7 children under 2 years, in 14% of those examined.

52 = 3 52 = 28
51 = 10 51 = 6
5 = 13 5 = 8

Without examination of the blood, all these persons would have been deprived of quinine therapeutics.

As regards the frequency of different forms of malaria, the following table for Dar-es-Salaam, 1908-1909, gives information.

<table>
<thead>
<tr>
<th>TABLE II.</th>
<th>There were found</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indians</td>
</tr>
<tr>
<td>April-June 1908</td>
<td>167</td>
</tr>
<tr>
<td>July-Sept. 1908</td>
<td>1,004</td>
</tr>
<tr>
<td>Oct.-Dec. 1908</td>
<td>1,001</td>
</tr>
<tr>
<td>Jan.-March 1909</td>
<td>594</td>
</tr>
</tbody>
</table>

In reference to mortality amongst children, in consequence of malaria, Zander states, that before the introduction of prophylaxis in places on the coast, of the total number of deaths amongst children under four years, 44% in Dar-es-Salaam, 47% in Lindi, and 75% in the higher situated Taboras, were due to malaria.

On the introduction of malaria prophylaxis into German colonies, the principle was laid down that it should always be preceded by a statement of the so-called endemic index, that is to say, by ascertaining what percentage of the inhabitants of one place were infected by malaria at the time. The researches, whenever possible, were extended over various quarters of the town, in order to discover what parts were seriously threatened. In doing this, it turned out, moreover, that not all parts of the population were equally attacked by the disease, or were equally predisposed to it. (See Tables—Indians and Negroes in Dar-es-Salaam.) Further, it is essential that the examination of the population be repeated at different seasons of the year.

1 By this are meant the ring forms of all three kinds of parasites, which could not be distinguished one from the other, and were not accompanied by the characteristic forms of Indians, or by gametes.
It is specially important with children of a year old, whether they have already gone through a rainy, i.e., a malarial period, or not.

In the German colonies the first place is given to fighting malaria with quinine. In Stephansort, in New Guinea, Robert Koch for the first time adduced positive proof that in a perfect hot-bed of malaria it is possible to reduce this disease to a minimum, nay, make it disappear altogether, and this by the exclusive aid of quinine.

Thus, on the island of Brione (Istria), Frank under Koch's superintendence, carried on a struggle against malaria in the years 1901-1902. At the beginning of the campaign in December 1900 there were 63% of the inhabitants infected with malaria. In the first nine months of the struggle, 22 cases in all occurred amongst laborers drawn from regions five years fever; from that time, in the next fourteen months, there were no fresh cases of infection at all, and only nine relapses.

The fight against malaria is twofold, consisting, (1) in the treatment of the sick, and (2) in the destruction of the parasites that have already made their way into the human organism—the "prophylaxis" proper. If the solution of these problems can be brought about, malaria must disappear.

Individual prophylaxis can be practiced according to an empirical scheme which has proved useful; that I have found that in the worst fever regions, on marches and expeditions, the dose of one gramme of quinine every fifth and sixth day is sufficient to guard against fever. Other authors recommend other methods; as to the value of the separate schemes, the last word has not been said. But it is certain that individual quinine prophylaxis is able to prevent the outbreak of malaria infection, and, on the other hand, that the use of the drug may be left to the patient himself, under the control of the doctor. It is a different thing with the general part of the fight with

1 This work does not belong to my present subject. I mention it here because it prepared the and completed the experiment of Stephansort.
the treatment of the persons infected: the latter can only be detected by the doctor or by a staff specially trained for the purpose, and their treatment must be individualized. The fight against malaria by this method can therefore only be begun and carried out under medical supervision.

In the year 1900 Koch found about 541 persons in Stephansort, New Guinea, 157 of whom harboured malarial parasites: 240 Chinese with 63 infected, 201 Malays with 13 infected, and 204 Melanesians with 137 infected were examined. In the beginning the infected persons were treated with one gramme of quinine, until the parasites had disappeared from the blood; from that date, for two months, every eighth and ninth day one gramme of quinine each was given. The result was a striking one, as appears from the number of patients admitted to the hospital:

- January, 34 admitted on account of malaria
- February, 15
- March, 15
- April, 15
- May, 5
- June, 1

Koch emphasizes that the months of January to May are notorious as being specially dangerous, and that also in the year 1900 the rainy season lasted right on into June. Nevertheless they succeeded in reducing malaria morbidity to a very slight amount, more especially as the cases of illness from it which had occurred from April to June were only relapses and not fresh cases of infection. And this success was obtained through the rational usage of quinine. It does not make any difference to the importance of this proof even if one admits that the conditions were rather favourable in Stephansort—being here the case of plantation labourers living far from their own homes and under complete control—and that the success was lost with the time as the control slackened. The proof I mentioned was given, and nothing more has been intended.
It was only natural that Koch's experiments in Stephanort were copied in the other German colonies and adapted to local conditions.

In German South-west Africa, the northern tropical districts of which suffer badly from malaria, Pfynder has undertaken to make practical use of Koch's ideas; because for these districts, where numerous small collections of water such as those which occur in footprints of cattle, horses and wild animals, serve as breeding-places for Anophelines, and where mosquito prevention by means of wire-gauze, screening the native huts, cannot be spoken of, quinine treatment and prophylaxis are the only possible methods. In Franzfontein and the surrounding settlements, Pfynder found 90% to 75% of the inhabitants infected with malaria. Every eighth and ninth day, ninth and tenth day, and every ninth, tenth and eleventh day respectively the infected adults were given one gramme at a time; the children correspondingly less. Certainly, it was not unimportant that quinine was given whenever possible in the form of hydrochloride in solution, and only in rare cases in wafer. In children, who easily rejected the solution, subcutaneous administration was adopted. This treatment was continued from two to three months. The results were very satisfactory. In Franzfontein, with its fixed and therefore regularly-treated population, the percentage of infected persons decreased from 75% to 9%, out of 165 persons only 2 new infections and 4 recidives occurred. In Tsumas 97% and in Canas 90% of infected persons were found at the beginning of the campaign. In the course of the following rainy season the settlements were free from malaria.

Koch's ideas of anti-malarial measures have been also applied to Dar-es-Salaam.

Dar-es-Salaam, at the time when Olhuug began his activities as director of the anti-malarial brigade, was a town of 14,000 to 15,000 inhabitants. The population consisted of Europeans (officials and officers stationed there for periods of one and
a half years, and merchants with engagements of longer periods. Indians, Goanese, Arabs and Negroes. The Europeans live partly on the peninsula facing north-east, and partly in the districts near the harbour. The Indians live in the adjacent blocks of houses situated more inland, and the native town is grouped around these. The larger portion of the town is surrounded by a depression where water remains for long periods through the dry season, and which renders the cultivation of rice possible. Along the shore wells spring up and form ditches and ponds. The town is therefore surrounded by a ring of water-collections which offer most favourable breeding-places to Anophelines.

The abolition of these water-collections, the land-level being but little higher than the sea-level at high tide, would have involved very great technical difficulty, and consequently would have been most expensive. Other measures, such as sifting of single water-collections with petrol, did not—as was to be expected—affect the number of Anophelines infecting the houses.

Willing first tried to establish the malaria index based on microscopic examination of the blood. Palpation of the spleen does not appear to have been practised. Willing accepts as a sign of malarial infections also the basophilic granulation of the red blood corpuscles, if he could find no other cause (anaemia due to ankylostomiasis) for its appearance.

For this purpose the town was divided into twenty blocks, and the inhabitants of these quarters were regularly examined without exceptions. Owing to the fixedness of the Indian and Goanese population, this examination could be fairly well carried out, but in the Negro quarters, however, this was an extremely difficult task, as they continually change their domiciles from village to town and vice versa. Therefore in the following table the Negroes mentioned have undergone a single examination.

* Due to other causes. — R. E. R.
From the table, in the column devoted to "first examinations," the malaria index is given fairly accurately, and shows that spontaneous immunisation in adults does not occur to any appreciable extent, and that therefore the treatment with quinine was justified also in the case of adults.

TABLE III

<table>
<thead>
<tr>
<th>Column</th>
<th>Children under 15 years</th>
<th>Children 15-50 years</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>27</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Negative</td>
<td>21</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>

The "first examinations" were made in August, September, and November 1901, and January to March 1902; the "later examinations" from March 1902 to March 1903—therefore after 1½ year's campaign at most.

On the contrary, compared to Zanzibar the malaria index of some villages further inland appeared rather high: of children up to one year of age, 77.3% were infected; of children up to five years of age, 37.5%; of children above five years of age, 17.4%; of adults, 21.7%.

The anti-malarial measures were limited to quinine treatment of all persons who were found infected, as well as those, naturally, who put themselves at the disposal of the doctor.

Quinine was given adults at first on three consecutive days and later on every fifth and sixth day, one gramme quinine muriate; after nine days' interval again three quinine days, and so on for two and a half to three months. Children were given a corresponding quantity of the drug in solution and a lump of
sugar afterwards; adults, mostly in form of tablets. One can see it was a question of a purely therapeutic anti-measure, and not one of prophylaxis.

Many of the details in Hisberg's interesting report were and three-quarter years after the anti-work cannot be referred to here, and only the "fact" is drawn on (resulting from Table III).

In one school not referred to, in the tables they were successful in reducing the number of infected persons from 215 (August 1900) to 55 (March 1901). Amongst the Indian population from July 1901-June 1902, 410 cases, from July 1902 to May 1903, 210 cases of malaria, came to the knowledge of the medical officer. It may be noted how the Indians gradually gained confidence with the medical officer, and so in the first half of the period more infections remained undetected than in the second half. In the Negro children, on the contrary, the results, though favourable, were not so favourable (decrease from 51 to 29). This can easily be understood because the Negro population is subject to constant fluctuations, and it is only seldom possible to continue the after-treatment long enough.

Statistics of adult Negros have been omitted from Hisberg's report; the 2% of infected adults are of little importance in proportion to the 26.4% of the children.

Hisberg proves in his report that the reduction in the malarial morbidity can have been caused neither through the climatic factors nor through other possibly adopted measures. The periods of rain and the numbers of Anophelines were not less during the time of the observation than previously, and the work of assimilation and petrolisation of the water-collectors have been practised so irregularly and to such a slight degree that these measures cannot have had great influence upon the large differences in the numerical value.

Hisberg rightly emphasises that only a very small staff—one medical officer, one nurse, one European and five coloured assistants—has been necessary for this successful struggle.
It is to be regretted that Ollwig did not calculate the total cost, as this calculation would have shown how cheap this method of anti-malarial measures is in comparison to other methods. Up to 1908 the number of native assistants never exceeded half a dozen, besides three to four Europeans, by whom 15,627 natives were examined microscopically and treated with quinine.

Subsequently anti-malarial work was continued in Dar-es-Salaam. For this work only one medical officer was available, whose time was greatly occupied with quarantine and other administrative work; the staff of assistants was not much augmented either. Ross-King's method of blood examination (the so-called thick film method) was adopted, and this method made it possible to discover even quite isolated parasites. The consequence was a remarkable increase in the positive cases since October 1907, and for this reason the numerical values given in Table V, before and after that date, are not to be compared with each other "without further consideration."

Other methods of anti-malarial measures could not be practised except to a very slight degree, as the money provided by the Government was just enough for quininium. In some houses mosquito-proof rooms—such as verandas—have been arranged, the petrolisation of water-collectors could naturally yield but little success.

In Tanga, the most important seaport next to Dar-es-Salaam, the anti-malarial work, according to the example of the capital, was not taken up until 1905 (Table IV). Besides one medical officer only three to four nurses understanding microscopical examination of the preparations were available. In addition to microscopical findings, tumours of the spleen decided the need of treatment. This treatment was commenced with one gramme dose in adults, and correspondingly lower doses in children, on two consecutive days per week, and was continued for three months. In all cases an enormous decrease of splenic tumours (from 1,040 to 1,040) and distinct improvement in
the general condition have been stated. Only in very rare cases this cure did not suffice to cause the parasites to disappear.

The population in Tanga being smaller and much more fixed than in Dar-es-Salaam, the result during the first year was more satisfactory. From March to June 1906, however, the number of infections increased threefold, which is explained by the extraordinary amount of rain during that time. In the course of the following dry season the index sunk to the level

<table>
<thead>
<tr>
<th>TABLE IV</th>
</tr>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Year</td>
</tr>
<tr>
<td>1905-06</td>
</tr>
<tr>
<td>January</td>
</tr>
<tr>
<td>February</td>
</tr>
<tr>
<td>March</td>
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<tr>
<td>April</td>
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<td>May</td>
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<td>June</td>
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<td>July</td>
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<td>August</td>
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<td>September</td>
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<tr>
<td>October</td>
</tr>
<tr>
<td>November</td>
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<tr>
<td>December</td>
</tr>
<tr>
<td>1906-07</td>
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<tr>
<td>January</td>
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<td>February</td>
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<td>March</td>
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<td>August</td>
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<td>September</td>
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<tr>
<td>October</td>
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<tr>
<td>November</td>
</tr>
<tr>
<td>December</td>
</tr>
</tbody>
</table>

As the year before
of the previous year. In 1907 to 1909, apparently another rise in the cases of malarial infection occurred in Europeans at Tanga; but this is due to numerous immigrations from further inland, the people in case of infection having the opportunity to get to the hospital in Tanga by means of the recent railway extension. Among the settled white inhabitants of the city of Tanga the malaria morbidity has gone back from 37% to 3% of the total strength.

Drainage of the town, petrocalcification—though not quite general—of water-collections, and deforestation of numerous uncultivated pieces of land, were undertaken simultaneously; also many Europeans' houses were provided with wire-gauze protection.

The increase of malaria during 1908 to 1909 (vide Table V) may be due to the hospital being more generally used by the patients from the district, which is more and more frequented by Europeans, and by people employed in the construction of the railway. In Dar-es-Salaam itself malaria has diminished to such a degree among the whites settled there in the European quarter, that individual quinine prophylaxis is no longer regarded absolutely necessary; rather, numerous officials have passed the whole of their one and a half years' time of service without taking quinine, and without once contracting malaria. Many, however, continue the quinine prophylaxis.

In the other settlements in East Africa, where medical officers and officials are stationed, no proper anti-malarial work is practiced to any appreciable degree.

From a general report on infected Europeans who have been treated by the medical officers, it can be concluded that, both together, the anti-malarial measures and the individual prophylaxis in Dar-es-Salaam as well as in Tanga have been a success.
The reports on the various Table V were the most accurate ones, as the majority of recorded infections were observed by a medical officer. The statements of "civil persons" (Table VI) are far less precise; only a small number of the malaria infections among them coming to the knowledge of the doctor. The figures showing the morbidity here have therefore been stated far too low, but, as these conditions do not change from year to year, it is quite permissible to compare the different years with each other.

With the colonized population matters are entirely different (Table VI). The percentage value in itself is here not standardized, as it was impossible at the repeated examinations to find always the same persons who had been treated with quinine. In addition to those there were persons who had come into town meanwhile, and who had been treated with quinine only insufficiently or not at all. Some other
<table>
<thead>
<tr>
<th></th>
<th>9990 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
<th>10,000 sq.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Cases of malaria</strong></td>
<td>325</td>
<td>313</td>
<td>325</td>
<td>313</td>
<td>325</td>
<td>313</td>
<td>325</td>
<td>313</td>
<td>325</td>
</tr>
<tr>
<td><strong>Deaths due to malaria</strong></td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Cases of headache</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Deaths due to headache</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>9990 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
<td>10,000 sq.</td>
</tr>
</tbody>
</table>
comparative instances must be sought, and they are given in the blood examination of the inhabitants of the suburbs of

<table>
<thead>
<tr>
<th>Year</th>
<th>White persons</th>
<th>Cases among</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1905-06</td>
<td>535</td>
<td>1,000</td>
<td>573</td>
</tr>
<tr>
<td>1906-07</td>
<td>735</td>
<td>1,065</td>
<td>1,167</td>
</tr>
<tr>
<td>1907-08</td>
<td>824</td>
<td>2,409</td>
<td>3,033</td>
</tr>
<tr>
<td>1908-09</td>
<td>2,032</td>
<td>2,232</td>
<td>4,264</td>
</tr>
</tbody>
</table>

Lala-see-Sallam, who had been examined since October 1907, in sufficient numbers without being given quinine.

The results concerning children, show clearly how much more favourable the mortality is among the town children who are partly under quinine treatment. This favourable consequence is not only due to a lesser danger of infection to which the children living in towns are exposed. And this can be seen from the single figures of morbidity which are higher alternatively in the centre and at the periphery of the town. If the danger of infection were less in the centre, its figures of morbidity also should be lower.

Clearly enough, this difference is not as pronounced in the case of adults, in whom acquired immunity plays a considerable part. On consulting Table IV on Tanganyk, it is quite clear that, under the circumstances prevailing in the seaports of German East Africa, the malaria among the natives can be kept on a certain level simply by methodical treatment of all
<table>
<thead>
<tr>
<th>Race and Sex of Dead</th>
<th>Age and Sex of Progeny</th>
<th>Race and Sex of Progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>1902 et al.</td>
<td>White, male</td>
<td>White, male</td>
</tr>
<tr>
<td>1903 et al.</td>
<td>White, female</td>
<td>White, female</td>
</tr>
<tr>
<td>1904 et al.</td>
<td>White, male</td>
<td>White, male</td>
</tr>
<tr>
<td>1905 et al.</td>
<td>White, female</td>
<td>White, female</td>
</tr>
<tr>
<td>1906 et al.</td>
<td>White, male</td>
<td>White, male</td>
</tr>
<tr>
<td>1907 et al.</td>
<td>White, female</td>
<td>White, female</td>
</tr>
</tbody>
</table>

**Notes:**
- Race and sex of dead.
- Age and sex of progeny.
the infected persons. But the statistician, as well as the practitioner in the midst of his work, comes to the conclusion, that a simple diminution does not suffice, and that this diminution is very fluctuating and strongly influenced by inscrutable factors. It is, therefore, the keen ambition of the medical officers in Jem-es-Salaam to obtain the means necessary for conducting anti-mosquito measures in the surrounding districts of the town.

At present, engineers are engaged on surveying the town and surrounding districts in order to work out, on the basis of their measures, a plan for the abatement of breeding and other Anopheline breeding-places.

**Kamerun.—**This German territory, however, has partly, up to this day, a very bad reputation as a hotbed of fever. In 1896-97 the malaria morbidity in Douala, the most important seaport, amounted to about 24.5; in certain months as many as 70% of the Europeans became infected; about 5% of the Europeans acquired black-water fever; and the total mortality caused by tropical diseases altogether amounted to about 3% (Table VII).

<table>
<thead>
<tr>
<th>TABLE VII</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Malaria among the European troops in Kamerun.</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strength (inhabitants)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases of malaria</td>
<td>1289</td>
<td>1663</td>
<td>2179</td>
<td>2839</td>
<td>3713</td>
<td>4803</td>
<td>6243</td>
</tr>
<tr>
<td>Deaths due to malaria</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cases of yellow fever</td>
<td>15</td>
<td>21</td>
<td>27</td>
<td>33</td>
<td>39</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>Deaths due to yellow fever</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Official statistics for the Kamerun are very incomplete, in consequence of the scattered nature of the single stations. The capital Douala is situated on a relatively favourable spot, i.e., on the brink of the rapid Kamerun River, about
6 to 12 metres above its highest level. Here was therefore given the possibility greatly to reduce the number of Anophelines through rainwater conductors and a regular system of drainage of several swampy places. In the latter years Ziemann has worked in connection with the local Government with great energy at the amelioration of the general hygienic conditions. The territory of the town itself has been planned, and cleared of all superfluous bush; and by means of straitly made roads the wind is given free passage. Severs effect rapid drainage of all minwaters. A sanitary brigade supervises the accurate and continued adherence to the specified measures. The brigade extends its surveillance also over the surrounding districts; hollows in the neighbouring wood, from where the Anophelines swarmed to the town, were drained or filled up, and if this was not practicable, saprol was poured over the water surface at regular intervals. Great credit is to be given, however, to the Government medical officers for their work of furthering quinine prophylaxis. It was as early as the close of the last century when F. O. A. Pikh recommended prophylactic use of quinine, and since then the value of this method, together with general hygienic improvements, has found full recognition with the majority of settlers. Also mosquito-proof houses are recommended and used as an anti-malarial measure, although this method is rendered much more difficult by the humid climate which soon destroys the wire-gauze.

The benefit resulting from the above measures can be easily seen from the figures indicating the malaria morbidity for Duala alone:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of inhabitant</th>
<th>Hospital frequented by</th>
<th>Hospital for malaria</th>
<th>Malaria percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1903-04</td>
<td>134</td>
<td>132</td>
<td>235</td>
<td>260</td>
</tr>
<tr>
<td>1901-02</td>
<td>135</td>
<td>124</td>
<td>235</td>
<td>260</td>
</tr>
<tr>
<td>1902-03</td>
<td>135</td>
<td>153</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>1903-04</td>
<td>134</td>
<td>153</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>1904-05</td>
<td>135</td>
<td>153</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>1905-06</td>
<td>134</td>
<td>153</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>1906-07</td>
<td>134</td>
<td>153</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>1907-08</td>
<td>134</td>
<td>153</td>
<td>255</td>
<td>255</td>
</tr>
</tbody>
</table>

The figures indicate that the malaria morbidity has been greatly reduced.
TOGO

In spite of the increase of the European population to double its previous strength, the number of severe cases of malaria treated in hospital had, with slight fluctuations, remarkably diminished.

It must be admitted that under such measures also the malaria among the natives is bound to diminish. At the policlinic, quinine is distributed gratis to all natives; the number of those who received quinine in 1907-1908 was 800. The treatment of so many infected people in one place is sure to lower the possibility of infection for the Anophelines and consequently the malarial infections in man.

The number of Europeans in the other settlements in Kamerun is too small, and is also subject to too many changes, to allow the possibility of deducting any conclusions about the value of certain anti-malarial work. The favorable effect of the malaria prophylaxis, and especially the individual quinine administration (prophylactic) together with general improvement in hygienic conditions, is evident anywhere.

The same holds good for the territory of Togo, with its three important places: Lome with about 6000, and Anzio and Pallone with about 3000 inhabitants each. The two former places are situated on a line of dunes directly at the sea, and landwards spreads a so-called lagoon. During the dry season, from October to April, there is so little malaria in Lome that Dr Kruger (no reference) recommends to suspend the quinine prophylaxis during that time. When, however, in April or May the rainy season commences, the malarial infections soon reappear, for the innumerable little hollows in the bed of the richly vegetated lagoon now fill up, and the Anophelines rapidly increase.

At places with such pronounced "malaria seasons" the quinine prophylaxis must be given first consideration. In Togo it is religiously practised by many Europeans, though not by all, as in 1907-1908 still 99 infected Europeans required medical attendance, 61 of whom, however, contracted the disease in
the bush." The work of a mosquito brigade is making for the diminution of the gnats (Siphoniptera) within the town and surrounding districts, whilst drainage of the lagoon has only just been decided upon.

(3) German South-west Africa.—This territory has badly suffered from disturbances, so that no precise statistics exist for this time. In 1907-1908 about 3,000 soldiers were sent home, and about 3,400 Europeans remained in March 1908. Among the latter occurred 307 cases of malaria with one death, and cases of blackwater fever, one of which with lethal result. The malaria is more general in the north of the protectorate which projects into the tropics and possesses a pronounced rainy period; the rainfall measuring from 400 to 700 mm. per annum (December till May). During this short period the Anopheles multiply enormously in the numerous puddles and pools, even in the footprints of horses and wild animals and the leaf-axils of certain plants. As water is there a question of great economical importance, petrolisation is not practicable, as, for instance, in the case of watering-places for cattle. The only measure to be taken into consideration seems to be fumigation.

During 1906-1907 a proper quinine prophylaxis—every fifth and sixth, respectively eighth and ninth day a 0.25 gm. gramme dose—was practised under the supervision of the local medical officers in the following stations: Namutoni, Zesfontain, Grootfontain, Waterberg, Otjo, Otavi and Omaruru. The result was a very unfavourable one: 11 to 90.6% of the persons treated suffered from malaria; in four stations more than 75%. The reason for this non-success has not been quite explained, as since 1907 no further report has been published. In many places it has been stated that the quinine tablets were not quite soluble; and it is probable that the form of malaria in question was of the most virulent type, against which the quinine was but of little use. The infection was mostly very slight.

It will be necessary to continue exact observations for many
years before one can possibly determine for what reason the quinine prophylaxis has failed just here. At the time any judgment upon this single observation would be premature.

14. The German possessions in the South Sea—The colonies in these regions are relatively small, and so is the number of Europeans. Only few medical officers are in practice there, and consequently the statistic material can add little to what has been said above.

It is worth mentioning that E.-C. found only quinaria on the "French Islands" (Bismarck Archipel) and only tropia in Mata. Some groups of islands are completely free from malaria.

The results of anti-malarial measures in the German Colonies can be briefly stated as follows—

1. The simplest and cheapest method has been found to be quinisation.

2. With carefully practised and well-supervised quinine-therapy and prophylaxis it is possible to exterminate malaria even in very badly infected places.

3. Individual prophylaxis with quinine suffices in susceptible persons (Europeans) to prevent with great certainty an outbreak of malaria. According to the probability of infection in a certain place, this prophylaxis must be increased or diminished.

4. Anti-malarial measures in the form of quinine treatment of infected persons have led to a decrease in the malaria morbidity, wherever they have been practised regularly, and for a sufficiently long period.

5. The smaller the native population of a place, the easier it will be to find all infected people and treat them thoroughly.

6. Quinine must be distributed gratis, and directly offered to the natives.

7. The treatment of infected persons with quinine, according
to Koch, is sufficient to keep the malaria on a low level among the natives in tropical towns.

8. The treatment of the natives with quinine together with individual prophylaxis leads to a remarkable decrease in the malaria morbidity among Europeans.

9. In many cases quininisation alone will not suffice to reduce the morbidity to a degree which is desirable in the politico-economic interest.

10. Which one of these three anti-malarial measures, quininisation, mechanical protection, and anti-mosquito measures, is the most important can only be decided upon according to the local conditions.
52. Campagnes Antipaludiques en Territoire Français

Le paludisme s'existait plus en France que sur de vastes points où il s'existait d'ailleurs peu à peu : la Vendée, la Solène, la Camargue.

La culture intensive succédant à de grands travaux d'assainissement agricole, l'accroissement du bétail et de l'otechnologie générale peuvent expliquer en partie ce recul du paludisme sur le territoire de la marque-patrie, mais il est difficile d'en préciser retrospectivement d'une façon parfaite toutes les causes.

La survie des Amphiptères au paludisme dans la France centrale est un fait très net qui montre que le paludisme peut disparaître sans que son vecteur soit exterminé.

Malheureusement la France, grande puissance coloniale, a dans ses possessions au-delà les mers un ennemi toujours présent dans le lieu paludique.

1. Campagnes antipaludiques en Algérie.—La plus belle de ces colonies a vu son sort longtemps disputé, non seulement pour des raisons politiques diverses, mais surtout à cause de son insalubrité qui, croient-on, devenait à jamais le séjour impossible aux races européennes. Alger était occupé en 1830, et en 1841 le Général Duvivier, un héros de la conquête, écrivait la phrase fameuse : "Jusqu'à présent, les cimetières sont les seules colonies toujours croissantes, que l'Algérie présente." 1

C'est en Algérie que le Professeur A. Laveran devait découvrir, en 1880, l'agent de la fièvre paludique et établir ainsi sur une base rigoureusement scientifique l'étude de cette affection en Algérie.

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mème temps qu'il ouvrait un nouveau chapitre de la microbiologie, celui des microbes pathogènes Protosomiens. C'est aussi en Algérie qu'un autre médecin militaire, F. C. Maillet, dès 1834, apportait de l'ordre dans la détermination des fèves intestinales des pays chauds, et, malgré les vives attaques de l'école hebraïsante, démontrait d'une façon définitive quelles sont les fèves, jusqu'alors hétéromènes, qui doivent précéder à la médication spéciale.\footnote{Le Professeur Trouvelot a aussi un ouvrage récent des erreurs de l'histoire dans le commerce deslinticulées. Paris, 1894, chez Frow.} Deux chimistes français, Pelletier et Caventou, avaient rendu possibles les beaux travaux de Maillet en isolant l'excès du quinacrine. C'est à Maillet que l'Algérie doit d'être devenue française; et le Dr Battard a pu dire qu'il a rempli de la façon la plus heureuse la formule du Membre Eugéniste: "C'est une joie en y ajoutant et guérir."

L'Algérie était devenue habitation, mais le poète national de l'assainissement y est resté. Encore a-prenant, heureux trop de vies et d'énergies y sont consommées du fait du paludisme. C'est pourquoi, à l'annonce de la belle découverte de R. Ross, sur le rôle des moustiques dans l'épidémie paludéenne, l'Institut Pasteur de Paris envoya, en 1902, une mission antipaludique, dont les essais furent conduits d'abord sur les points de Chemin de Fer. Mais dès 1904 M. le Gouverneur-Général Jomard demanda à M. Roux, Directeur de l'Institut Pasteur de Paris, d'étendre ces essais aux localités les plus paludéennes de toute l'Algérie; il leur confia une précieuse sollicitude, et les appuya constamment de sa haute autorité.

**Tarième.** L'Algérie occupe une surface approximative de 300,000 kilomètres carrés. La partie habitation figure un parallélogramme allongé de l'est à l'ouest entre le Sahara et la Méditerranée. Sur le bord même de la mer surgissent des chaînes de montagnes dirigées également d'une façon générale de l'est à l'ouest, et dont les sommets dépassent rarement 2,000
Entre ces montagnes ou entre leurs contreforts s'ouvrent des vallées et des plates-bandes de la Sbaa, de la Soussmassa, du Chelif, plaine de la Mzab, Hauts Plateaux, qui constituent autant de régions distinctes par leurs caractères géographiques, climatologiques et physiques. La faune, la flore, la climatologie sont aussi d'abord méditerranéennes. Une autre des zones humides limitées au Sud par la ligne qui correspond aux chutes d'eau minima annuelles de 40 cm, représente la partie colonisée par les Européens. Plus au Sud c'est le steppe, pays des Nomades, du mouton, du chameau. Plus au sud encore c'est le désert du Sahara, climat continental, et qui sépare définitivement l'Afrique de l'Europe que la mer est la Méditerranée.

En raison de la faible hauteur des montagnes et de l'abondance des neiges éternelles, le régime des cours d'eau considéré en arbre est essentiellement torrentiel. Les marais des plateaux basses et les marais subsistant en été dans la plaine sont les principaux gîtes à Anophèles.

Habitations—Sur ce qu'ils appelle habitant (au sens de 1966) 5,23,750 homme, dont 77,910 Européens et 4,10,950 indigènes, les premiers agglomérés surtout dans les villes et les villages, les seconds quarts dans la campagne. Les indigènes, tous de race blanche : Arabes ou Berbères arabisés dans les plaine, Berbères dans les montagnes ou le désert (Kabyles de la grande et de la petite Kabyles, chasseurs de l'Elfe, Tuaregs du Sahara), possédaient à la vie que je l'ai montré avec mon frère, une certaine immunité relative contre l'hématop得起e du paludisme, qui leur permet d'échapper au miasme dans leur sang périphérique, sans présenter de symptômes morbides (exactement comme les populations négres de l'Afrique d'après ce qu'ils avaient déjà vu, H. Koch, H. H. Stechels et H. Leblancher). Cet état d'immunité relative ou de paludisme latent est très dangereux pour la collectivité car ces "porteurs d'hématop得起es" qui souffrent peu, eux-mêmes, en étant normal de leur
infection, sont toutefois susceptibles d'infester à tout moment les Anophèles.

Les sujets exposés au paludisme sont donc en premier lieu les colons immigrants, et les indigènes provenant de régions saines. Le degré de danger encouru par eux dépend surtout du voisinage d'indigènes en état de paludisme latéral, car il y a des Anophèles partout en Algérie, sauf dans les grandes villes. Le préjudice pour les colons établis dans une exploitation provient de ce que l'infection ne reste pas unique, mais est suivie, en règle, de réinfections successives qui se produisent avant que l'immunité relative n'ait pu être acquise. Les Européens qui existent à ces réinfections présentent ensuite, comme les indigènes, une immunité relative existant avec un paludisme latéral.

Les Anophèles—Les Anophèles de l'Afrique du Nord actuellement connus sont : 

1. Anophèle maculipennis Meigen, l'espèce la plus répandue. On le trouve partout sauf dans les villes ; il habite le littoral, les plaines, les montagnes, les vallées, le steppe, le Sahara. En moyenne, il est infecté dans les pays paludiques.

A. aegeritii Theobald, espèce vicariante de II. diffusus espèce sylvicole, faunique. On le trouve aussi infecté par des sporozoa de Plasmodium.

Pyróphiles maculipennis Theobald et Serg. Vallées des régions accidentées. On le trouve également infecté par des sporozoa de Plasmodium.

Pyróphiles aegritii Theobald. Littoral des Steppes et du Sahara.

Pyróphiles sylvicolus Theobald (cité par A. Billet, Sahara). Une première épizootie de fièvre benign apparait au printemps, la firme maligne prédomine en été et en automne. La quarte se montre surtout en automne et surtout dans certaines époques.


INDIVIDUAL PROPHYLAXIS

Prophylaxie antipaludique d'un particulier.

1. Prendre tous les jours une dose de 0.20 centigrs. de bichlothydrate de quinine (enrobé dans 0.30 centigrs. de sucre), pendant tout le temps que l'on passe en pays infecté, et pendant 15 jours après la sortie de ces pays. Rédiger tous les jours une note de chaque dose. Enfin nous n'avons jamais dormi en pays paludéen, sans la moustiquaire portative que nous avons toujours dans nos bagages et que nous montons tous les soirs.

Un certain nombre d'officiers, de fonctionnaires ou de colons contraints à traverser des régions malades ont adopté la pratique de ces mesures de préservation personnelle.
qui est le plus fréquemment observé est la quininisation préventive. (2). Une collectivité (compagnie de chemins de fer, exploitations agricoles, minières, grandes administrations) doit éviter d’installer ses postes, ses garages, dans le voisinage des gîtes à Anophelines et des agglomérations indigènes. Le Service antipaludique en Algérie est consulté en principe chaque fois que l’on construit une ligne de chemin de fer et que l’on fonde un nouveau village de peuplement européen. On a pu faire prévaloir parfois le choix de certains emplacements moins exposés que d’autres à la contagion paludique.

Les collectivités (agents des chemins de fer et des Services publics, troupees, ouvriers agricoles, mineurs, etc.) peuvent être facilement soumises à une prévention préventive par les petites doses journalières. Il est bon dans ces cas de faire tenir un registre des prises de quinine pour que l’on sache bien comment est absorbé le médicament.

Enfin ces collectivités peuvent être également protégées par les grillages métalliques posés aux ouvertures des habitations : défense mécanique collective.

C’est là un procédé de luxe qui coûte fort cher et ne peut être proposé qu’en faveur de personnes d’un niveau social assez élevé pour prendre soin de leur confortable. Nous tâchons de rendre cette défense mécanique le plus automatique possible, pour demander très peu d’attention et de bonne volonté aux occupants des habitations. C’est ainsi que nous faisons établir les volets à l’intérieur des fenêtres de façon à ce que le grillage des fenêtres soit extérieur à tous les bâtiments, et, par conséquent, n’ait pas besoin d’être percé de lucarnes pour le maniement des verrous, crochets au Beaux destinés à assujettir les volets. Si les volets sont extérieurs, par exemple dans les maisons déjà construites que l’on veut grillerger, nous préférons pour les grillages les chassis à galvaniser dont la fermeture est automatique.
Pêche de poissons, site de Amplefleurs.
(3) Le rôle de l'eau dans la prophylaxie antipaludique peut être compris ainsi:

L'exécution des grandes mesures antilarvaires: Catéchisme de désherbage, grandes plantations dans les marais, relövement des montagnes, petites barrières dans les limites basses, régularisation des cours d'eau, surveillance des barrages, réservoirs, etc. Mais ces énormes travaux, qui coûtent très cher, ont seulement un but principal d'assainissement agricole; l'hygiène antipaludique ne peut intervenir ici qu'à titre accessoire, pour appuyer tel projet, contre-indiquer tel autre. D'ailleurs ces grandes mesures antilarvaires ne sont pas complètement efficaces par elles-mêmes; elles ne font que rendre possibles les petites mesures antilarvaires et surtout l'hygiène agricole. Cette-ci, en drainant et en permeabilisant le sol, en supprimant les moindres mares, en utilisant toute l'eau des pluies et toute l'eau des sources, aboutit, en poursuivant un but purement culturel, à un résultat réellement antipaludique. Nous avons souvent constaté qu'un grand canal de dérivation était surpeuplé de larves d'Anophèles, tout comme le marais qu'il remplace. Mais le marais était inaccessible, tandis que des deux berges du canal on peut atteindre et détruire les larves d'Anophèles.

Cet exemple montre bien ce que sont, à notre sens, les petites mesures antilarvaires. Dans le canal dont il s'agit, les larves apparaissent constamment, quoique masquées par une eau de surface, et ne cesseront jamais de se développer, au contraire du marais, où on peut éliminer les larves d'Anophèles une fois pour toutes. Par conséquent, les mesures de destruction des larves doivent être répétées indéfiniment sur les parties du canal voisines de lieux habités (dans un rayon de un kilomètre et demi) et c'est là le principal caractère des petites mesures antilarvaires: de n'avoir qu'une efficacité temporaire. Elles
tion purément et simplement en échoe la pullulation des larves pendant le temps où elles sont mises à exécution. On a donc intérêt à maintenir indemnes de larves les enquêtes d'une agglomération importante, mais il faut évidemment que la valeur économique du groupement à échapper soit assez grande pour justifier les dépenses engagées. Il est une autre utilité des petites mesures antilarvaires, c'est celle de supprimer temporairement les vecteurs de la contagion et, par suite, d'empêcher pendant ce temps les réinfections. Elles permettent aussi la guérison des anciens individus, que l'on aide, d'autre part, par la quininisation curative. En somme, à mes sens, les petites mesures antilarvaires auront pour lui, non pas seulement d'éviter des infections des individus, mais aussi de permettre la guérison des anciens indétisible.

Le type des petites mesures antilarvaires est présenté par les coulées de l'eau stagnante nuptes suivant les besoins, 2 ou 3 fois par an, et les péristalys, renouvelles tous les quinze jours (ou plus, suivant le climat selon les années). Les mêmes artifices, qui rendent impossible la vie des larves dans les aubes, permettent des résultats qui leur suffisent, peuvent être variés. Je vais en donner un exemple typique le procédé suivant que nous avons appliqué déjà souvent.

Soit une source, une fontaine, un abreuvoir, dont l'eau d'écoulement forme des gîtes intarissables et permanents. Nous faisons creuser, au lieu d'un seul canal, deux petits canaux d'écoulement fermés à leur origine par une vanne. On laisse l'eau s'écouler par un seul canal pendant huit jours : les œufs y sont pondus, les larves naissent, se développent. Au bout de huit jours nous baissons la vanne de ce canal et ouvrons l'autre : les larves qui ne sont même pas encore arrivées à la nymphose meurent sur la houle qui s'achève au fond du canal abandonné par l'eau. Ainsi, sans aucune surveillance, cinq minutes de travail toutes les semaines suffisent à empêcher tout développement des larves dans cette eau d'écoulement.

Les mesures contre les adultes telles que les fumigations de
l2

pouvoir de prétendre ou de avacer la prééminence de pouvoir du pyridine de périthracea de l’utiliser pour un rôle secondaire dans la lutte antipaludique.

C’est au contraire la quininaisation qui a montré son importance. Il est peut-être également à l’assaut d’une ébauche de l’algérie. Nous avons d’abord que dans notre pratique nous avons pu la pratique curative exacte comme la quininaisation étant considérée comme la quininaisation préventive. Il fut, en effet, nécessaire de traiter les foyers, vraiment médical, c’est à celui qui possède par des foies pour.

D’autre part, il est bien plus commode d’apporter une technique unique qui s’applique aussi bien aux sujets indigènes qu’aux anciens habitants d’un pays où le paludisme est assez commun. Enfin la compare aux index périthracea par la paludisation des foyers avant et après les campagnes antipaludiques nous donnent la valeur efficace des petites doses paludiques longtemps répétées. C’étaient en sorte que même les petites doses de quinine suffisent à faire disparaître les parasites du sang périphérique bien avant la guérison totale de l’infection paludique. Les individus ainsi “isotypés” alors même qu’ils ne sont pas encore guéris, sont déjà rendus insensibles pour la collectivité. Au moment où les procédés de la quininaisation préventive et curative sont mis en œuvre de plus en plus dans tous les pays paludiques, on nous permettra de rappeler que depuis longtemps en Algérie, à la suite de Mallet, les populations civils et les médecins de l’armée ont procédé et apporté quelques sortes de quininaisation. Je citerai, parmi les expériences les plus nettes, celles de Sezary et celles de Cortelet.


17493.2. (Contrastes de la Période bours de la Malaisie par la GN. Tho. médecin, Marseille, Alg.)
ANTIPALUDIQUES EN TERRITOIRE FRANÇAIS

très malsains, des familles entières en parfait état de santé, au milieu de voisins toujours malades. Et non seulement les âges
disparaissent, mais l'appétit augmente, les couleurs du visage,
l'embouvoire révèle, en un mot, l'apparence de la santé parfaite...; tantis qu'autour de ces personnes tout le
monde saisit les influences fatales du milieu.

Conséquences arrivent en plus exactement aux mêmes con-
clusions : "L'administration de petites doses quotidiennes de
quinine a pour résultat de prévenir, soit l'éviction, soit le retent
du paludisme."

Les médecins de l'armée employent depuis longtemps en
Algérie la quinisation régulière préventive, et les résultats
dépendent du soin qu'on apporte à observer leurs prescriptions.

Le Service antipaludique en Algérie emploie des égratages
léonardins pour les hématoxyline de quinine, semblables à
celles de l'État italien et contenant vingt centigrammes de
sels comprimés et emballés dans trente centigrammes de sucre.

Nous faisons distribuer une dragee par jour aux adultes, deux
dragées dans les régions très paludiques, ou bien trois dragées
tous les deux jours, ou tous les trois jours.

Pour assurer une exacte administration de la quinine,
éviter tout abus et tout accident, nous avons nécessaire de
distribuer les dragees par des quininistes, agents des
services publics ou personnes de confiance, chargées temporaire-
ment de ces fonctions pendant l'été, moyennant rétribution.

Les quininistes sont encore plus précieux que les quininisa-
teurs, à cause de leur facile accès auprès des femmes musulmanes.

Le quininisateur distribue lui-même aux moments fixés : tous
les jours, ou tous les 2 jours, ou tous les 3 jours, la quinine aux
personnes inscrites sur un registre ad hoc. Il fait ingérer les
dragées en sa présence et note les prises sur son registre.

Nous évaluons les résultats de cette quinisation par la
comparaison des indices endémiques avant et après la campagne.

En règle générale ce sont les indices paludiques que nous relevons,
et, nous ne quininisons, d'habitude, que les agglomérations où
L'index splénique dépasse, au printemps, 10%. Lorsqu'il le
peut, on relève aussi l'index karyotypique.

La quininisation est rendue difficile en
Algérie par le fait que ce pays est réuni à la France
européenne à la loi de Germinal au XI qui donne aux
Pharmaciers le monopole de la vente de la quinine. Il a fallu
donc que le Gouvernement central de l'Algérie veuille avec
les Pharmaciers de la Colonie que entende aux termes de
laquelle les dragées de chlorhydrate de quinine vendues au
public sous des marques de garantie spéciales, sont venues à
un tarif particulier, aussi bien que possible qu'augmentent un
bénéfice aux Pharmaciers. C'est-à-dire que de ces
dragées des actes de quinine confiés à des agents des
Services publics autorisés à recevoir, au prix marqué, les dragées au
public. D'autre part les Pharmacists livrent ces dragées au
Service antipaludique, pour la quininisation du Réserveur
de virus, sans prélever de bénéfice. En somme cette entente, si
donne ses fruits, mettra à la disposition du public, dans
toute l'Algérie, de la bonne quinine, à bon marché, sous une
forme agréable, et permettra à l'État d'entreprendre avec le
moins de frais possible la quininisation publique de l'énorme
Réserveur de virus constitué par des millions d'indigènes, en
majorité indigènes.

Si nous souhaitons résumer le mode d'action de l'État Algérien
doing la lutte antipaludique nous disons que ses efforts princi-
paux portent sur la réduction du Réserveur de virus formé par
les indigènes anciens infectés. Cette réduction du Réserveur
de virus est procuree par la quininisation par petites doses
quotidiennes, et elle est facilitée, accélérée dans toutes les
localités où la chose est possible, par l'organisation de petites
mesures antilarvaires.

Le service antipaludique a institué des campagnes anti-
paludiques expérimentales dans trois champs de démonstration : un par département : Montebello (Alger), Trouville (Oran),
Mondoli (Constantine). D'autre part il subventionne et aide
les campagnes locales organisées suivant les mêmes principes par les médecins collaborateurs résidant dans des villages fluviaux et dirigé les mesures prises sur les niveaux des chemins de fer, dans les immeubles administratifs. Enfin il propage les connaissances nouvelles sur l'épidémiologie et la prophylaxie du paludisme.

Une ligne algérienne contre le paludisme. Selon en 1903 par les Prof. Mennau et Sédif, il est agréable à la vaccination des dents de merveille sans le paludisme.

Résultats.—Nous examinons ici les résultats obtenus dans les campagnes de déviation du Service antipaludique. Il donne une idée des résultats obtenus par les diverses campagnes menées ailleurs.

118 départements d'Algérie — Mesures antipaludiques et quantitatives.

Avant la campagne.

En 1905, 75 mères, 12 enfants, il se produisit un seul cas mort.

Après la campagne.

En 1905, 74 mères, 10 enfants, il ne se produisit que deux cas morts.

Depuis le début de la campagne (1905) il y a eu à Montebello 10 naissances. Aucun de ces enfants n'a eu le paludisme jusqu'à présent. Le fait est unique dans l'histoire de Monte-Bello.

L'Antipaludique, non dévastateurs, pourtant servent de témoins.

En 1905, 5 personnes indemnes, 9 premiers invasions.

1906, 25 cas de nouveaux, 12 cas par accidents premières invasions.

1907, 2 personnes indemnes, 4 premiers invasions.

1908, 17 personnes indemnes, 5 cas de première invasion.

1909, 3 personnes indemnes, 7 cas de première invasion.
(2) Département d'Oran — Tractions (mesures antilarvaires et quininalisation).

Avant la campagne:

En 1905: Sur 42 enfants, 10 grosses rates, 29\%

Après la campagne:


En 1907: Sur 17 enfants, 2 grosses rates et 1 cas : Sur 36 habitants, 11\% de la population.

En 1908: Sur 17 enfants, 1 grosse rate, 6\% : Sur 36 habitants, 11\% de la population.

Depuis le début de la campagne 1906, il y a eu 2 tractions

avortées. Deux enfants seulement se contaminèrent

(1 en 1906, 1 en 1907).

Sainte Léonie — (Mesures antilarvaires et quininalisation — elle est défectueuse)

Avant la campagne:

En 1906: Sur 31 enfants, 12 grosses rates.


Après la campagne:


En 1908: Sur 31 enfants, 10 grosses rates, 32\% : Sur 36 habitants, 11\% de la population.


Localités du voisinage, non défendues, pouvant servir de témoins:

En 1906: Sur 12 personnes indemnes, 12 premières infections.

En 1907: Sur 2 personnes indemnes, 2 premières infections.

En 1908: Sur 12 personnes indemnes, 12 premières infections.

En 1909: Sur 1 personne indemne et 10 premières infections.

(3) Département de Constantine — Monasté (mesures antilarvaires et quininalisation).
Avant la campagne:

En 1906: Plusieurs cas d’hémoglobinurie et plusieurs cas de première invasion chez les nouveau-nés.

Après la campagne:

En 1907: Sur 773 personnes, 1 cas de première invasion.

L’indice endémique de Mondovi:

En automne 1907 est de 78 %

LocaHités voisines, pouvant servir de témoins:

En 1907: 1 cas de première invasion.

Penthèvre: (Mesures antillariennes et quininéogenes).

Après la campagne:

En 1907: Sur 260 Européens 2 cas de première invasion.

L’indice endémique de Penthèvre:

En automne 1908 est de 70 %

LocaHités voisines, témoins de Penthèvre:

En 1907: 1 cas de première invasion.

En 1909: 450 kilos de dragées de quinine, par les médecins collaborateurs du Service antilarique, qui avec un zèle et un dévouement dont on ne saurait trop leur savoir gré, ont ajouté à leurs occupations professionnelles la charge de com-
Batter l'épidémie la plus répandue, sinon la plus grave actuellement, en Algérie.

**Budget de la lutte anti-paludique en Algérie.** Depuis plusieurs années, les campagnes anti-paludiques existent au long du littoral (cf. dont 11 ans précédant celle-ci). Provenant d'une masse humaine par an : Personnel permanent : de 10 à 15 000 francs. Personnel temporaire (élimination de larves) : de 5 à 10 000 francs. Arène de quinca : de 10 à 20 000 francs. Vérins mises en place : 15 à 20 000 francs. La défense mécanique est payée par chaque administration compétente.

Le budget total de l'Algérie est de 12 millions de francs.-

Il. **Campagne anti-paludique en Tunisie.** La Tunisie, que continue, à l'Algérie, est sur 34 000 kilomètres carrés habitants dont 1 000 000 d'indigènes.

Il est aussi certain que toutes les régions basses et arrosées, les plaine marécageuses, les vallons paramètres, les vallées et sources sont frappées par le paludisme au printemps épidémie de terre haute, et en été et automne, même si le climat est constitutionnellement désavantageux. Certaines régions sont de la nature méridionale de la Tunisie. 7. **A. Nicole,** après une première expérience de lutte anti-paludique en 1903, obtint la création d'un service paludique rattaché à l'institut Pasteur de Tunis, en toute époque. Ce service a pour but principal de défendre contre le paludisme ces centres de civilisation en enseignant aux colons les dangers qu'ils encourrent et les précautions à prendre pour les éviter et en remettant à l'administration sur les mesures prophylactiques d'ordre général ou local qu'elle seule peut entreprendre. En conséquence, des travaux sont faits dans un but...
de propagande et d'organisation dans les localités les plus exposées : il a été établi, en particulier, les défenses organisées sur les réseaux des chemins de fer et dans des compagnies d'exploitation des phosphates, les règlements édictés pour la déclaration obligatoire du paludisme dans la ville de Tunis.

Pour un certain nombre de localités les conditions exactes du paludisme ont été déterminées. Pour propager les principes de la lutte antipaludique, des distributions sont faites de brochures, d'affiches. Enfin le service antipaludique ainsi que le gouvernement tunisien distribue gratuitement des dragées de quinine.

Le privilège des pharmaciens n'existant pas en Tunisie, pays de protectorat, l'État a pu y organiser la vente de la quinine. Un arrêté du 15 juin 1900 charge les débiteurs de tabac de la vente de la quinine dont ils s'approvisionnent à l'entreprise des Montecas, le minimum d'approvisionnement et le prix de vente sont réglementés. Il n'a pas eu de dépôt de quinine en dragées de 100 grammes.

Sur les lignes de chemin de fer, où les mesures sont bien prises et surveillées, on constate l'absence presque complète de paludisme. Dans les centres de colonisation, où l'importance du paludisme est plus difficile à mesurer exactement, on constate la progrès de l'hygiène du public, et une amélioration notable de l'état général. Les hôteliers indiquent une baisse de quelques milliers de francs, apportés par des mesures de surveillance et des réunions du Directeur du service, achat de quinine, publications de propagande.

II. Campagnes antipaludiques en Corse — Territoire. — La Corse est une île allongée du Nord au Sud sur 200 kilomètres de largeur et une largeur maximale de 90 kilomètres. L'île est traversée par quatre chaînes de montagnes, dont la plus importante est la chaîne des Calanques.
de la mer à l'Est par une plaine longue de 130 kilomètres et large de 6 à 20 kilomètres. Cette plaine orientale couvre 100 000 hectares, près du quart de la superficie totale. Elle est faite entièrement de politique, à type colloïdal-proténique.

Population.—Le Dr Thiers estime à 80 000 le nombre des habitants qui subissent annuellement les atteintes du paludisme (en un chiffre total de population qui n'aident pas juxtaus entendus) pour le département tout entier.

Améliorations.—L'espèce dominante est l'espèce auxiliaire en ménages.

Mesures adoptées.—L'État a pris diverses mesures importantes en France. Ce fut le Président A. Laurenz qui, en 1897, préconisa la création d'une école locale pour l'enseignement du paludisme à ce pays. Une bonne école contre le paludisme fut fondée à l'Est par le Dr Béton, et depuis la mort de ce prophète savant, elle est pérenne par le Dr Thiers.

L'action des médecins—Sociétés étant surtout mises, elle consiste d'abord en une cure de séduction dans le département de brouillards de vulgarisation, établis de cartes postales, pour d'affiches mettant en garde contre la pâture des moustiques, conseils sur la façon de prendre la quinine, recueillement sur la façon d'organiser la production médicamenteuse, installation et entretien de quelques maisons prophylactiques, destinées à servir de modèle.

La Ligue a obtenu des pharmaciens que ses adhérents puissent se procurer la quinine au prix de quinze centimes le gramme, prix bien inférieur aux prix en usage auparavant. Elle a dit de la Compagnie des Chemins de Fer départementaux, d'abord, les clauses Administratives de l'État envoyées à

1. ANNU.D. 1897, "La Ligue, 451, Rue de l'Odéon".
2. Connaissance de la Ligue, 33, Rue de l'Odéon, 1897.
3. "La Ligue, 451, Rue de l'Odéon".
4. ANNU.D. 1897, 451, Rue de l'Odéon, 1897.
5. Connaissance de la Ligue, 451, Rue de l'Odéon, 1897.
ANTIPALUDIQUES EN TERRITOIRES FRANÇAIS [Dec.]

adopter les toiles métalliques et la prophylaxie quinique dans les localités réputées paludéennes.

Résultats obtenus.—Au point de vue moral, l'opinion publique en Corse est avertie, à l'heure actuelle, des dangers et des causes du paludisme, ainsi que des moyens d'y remédier. Au point de vue pratique la morbidité a diminué en certains points bien surveillés : elle est tombée parfois de 40% à 12%, mais il ne s'agit que des cas de première invasion, les récidives sont encore assez nombreuses. C'est que le zèle des médecins qui dirigent la litière antipaludique et des Chefs d'Administration n'est pas toujours secondé par la bonne volonté des intéressés eux-mêmes. La question du paludisme devrait constituer une des principales préoccupations de la Commission gouvernementale chargée actuellement d'étudier les moyens du relèvement économique de la Corse.

Budget.—Les cotisations des Sociétaires sont subventionnées par la Ligue Corse ainsi qu'une somme de 1000 francs que lui attribue le Professeur Laveran sur des fonds mis à sa disposition par la caisse des recherches scientifiques.

IV. Campagnes Antipaludiques dans les Colonies Françaises.—

Le Ministère des Colonies a publié en 1903 des Instructions concernant les mesures à prendre contre les maladies individuelles, epidémiques et contagieuses. Mr le Médecin Inspecteur Général Kermorgant y consacre 22 pages à la prophylaxie antipaludique. Il revient en 1906 sur cette question dans un article sur "La Prophylaxie du Paludisme." Sur ses instructions, l'étude des Culicides fut poursuivie dans toutes les colonies Françaises et montra, entre autres choses, que les seules colonies exemptes de paludisme : la Nouvelle-Caledonie et Tahiti, sont en même temps indemnes d'Anopheles.³

Mais en constate surtout des essais individuels de grillages des habitations. Et d'autre part, depuis longtemps, l'initiative

³ Voir Annales de l'Institut d'Hygiène et de Médicine Coloniale, 1905.
⁵ La commissiončenomMe Mr le Médécin Inspecteur Général Kermorgant des problèmes qu'il a bien voulu me communiquer.
de procéder de la quinine préventive dans les pays paludismes ou en expéditions coloniales est livré aux militaires.1

Les renseignements que nous avons pu recueillir parmi les documents publiés au Ministère des Colonies sont lassants—

La Réunion—ile de 2,250 kilomètres carrés et 150,000 habitants touchés depuis 1897 par le paludisme. Deux espèces d’Anophelines: A. quadrimaculatus et P. pyrethres savayt. En 1902 le Colonel Servillet, commandant suprême des troupes éclata des règlements, qui furent bien appliqués dans la population militaire, pour la quinimisation préventive et curative, l’emploi obligatoire des moustiquaires et la destruction des moustiques dans le voisinage des postes et casernes.

La mortalité atténuée assez élevée dans les statistiques militaires devient null en 1904 et 1905, alors que la mortalité dans la population civile subissait une progression importante.

Après le départ de cet officier supérieur, les mesures ne furent pas aussi bien surveillées et les attaques de paludisme recommencèrent.2

Madagascar—Un décret du 20 Octobre 1905 autorise le Gouverneur-Général de Madagascar à prendre par voie d’arché toutes les dispositions nécessaires pour que les soldats de quinine soient mis à la disposition de tous et au plus bas prix possible.

Le Président de l’Académie de Médicine pour les expérimenter militaires de Madagascar sont préparés par des tissus métalliques.3

Africain quadrimaculatus—Sénégal—Le Dr Thieux qui, après le Dr Marchoux a spécialement étudié le paludisme du Sénégal, rapporte les mesures prises pour le soumettre en 1904-1905 la ville de Saint-Louis (25,000 habitants).4

5 A. Thioux et M. Marchoux, "Le Paludisme en Sénégal pendant les années 1904-1905."

On procède au remblaiement des marais de la pointe nord de la ville de Saint-Louis, des marais du faubourg de 2e. Pour ces derniers, on a instauré un système de drainage avec siphons s'amonçant d'eux-mêmes à marée basse et ne fonctionnant plus à marée haute. On procède à des pêtrolages dans la ville de Saint-Louis; quelques essais de défense mécanique ont été tentés. La ligne du chemin de fer de Saint-Louis à Dakar a toutes ses gares et ses logements d'employés protégés par des toile métalliques.

**Territoire des Kébités de Soud.**—Le Dr De Le Molay applique en 1906 les mesures antilarvaires à l'assainissement de Conakry (4000 habitants) bâtie sur île de Tumbo, une des villes les plus paludisées d'Afrique. Il y organisa des brigades à moustiques qui eurent pour mission de remblayer les bas-fonds, de drainer les marais, de pétroler les marais.

**Territoire du Sénégal et Négro.**—Le Dr Bouffard* conseille, voir exemplaire à l'égard pour l'Europe une cure quinquennale (d'une quotidiennement de 25 centigrams augmentée en cas de danger spécial) prolongée deux semaines après le retour en pays sauv.

Il y joint l'usage de la moustiquaire individuelle.

Il estime par contre la quinquisation des indigènes impossible dans ces pays et croit les mesures antilarvaires susceptibles de diminuer le paludisme chez les Négro. Il trace un programme de travaux à exécuter suivant que les agglomérations indigènes sont en plaine ou en montagne. Enfin l'Administra-

tron peut agir efficacement en obéissant aux règles de l'hygiène antipaludique l'emplacement des villages.

*Indochine.* — Comme pour Madagascar, un décret autorise le Gouverneur Général à délivrer aux indigènes de la guerre gratuitement la ils bon marché.
By H. C. Ross, M.R.C.S., L.R.C.P.

Director of the Royal Southern Hospital Researches, Liverpool

Lately in the service of the Egyptian Public Health Department

39. Mosquito Reduction in Egypt.—Before considering the history and details of the several campaigns started and in progress in Egypt, it will be better to discuss briefly the local conditions which affect a sanitary measure of this nature. Egypt owes its very existence to the Nile. Were it not for that river Egyptian territory would merely be a part of the desert. Except on the Mediterranean Coast in the winter months, rainfall is a negligible quantity; so that stagnant pools of rain-water like those found in the tropics are unknown. The only natural collections of water in the country are the Nile, the two Bitter Lakes through which the Suez Canal passes, a fresh-water lake—derived from the Nile—at the Oasis of the Fayoum, and two shallow sea-water lakes near the Mediterranean Coast. The Nile itself flows through Egypt without receiving a single tributary.

Although the natural collections of water are so few, Egypt may be defined as a veritable marsh surrounded by desert. The marsh is, of course, confined to the narrow limits of the basin of the Nile, and the water is the most valuable asset of the country. Canals and irrigation channels are everywhere, and the native spends his existence raising the water either out of the Nile itself, or from the canals, or from wells, on to the soil itself. In consequence, if there are few natural collections of water, the country is riddled with puddles and artificial breeding-places for mosquitoes. The peculiar cosmopolitan nature of the population must
be mentioned. The term "native" refers to the local subject, and it is used in contradistinction to the Europeans, many of whom, as far as their instincts regarding sanitation are concerned, are not very superior to the native. Almost every nationality finds a home in Egypt, and foreign countries do not appear always to send their best subjects when Egypt is singled out as a settlement for them. The native himself is fairly easily led, especially the lower classes; but when he becomes educated, especially in Europe, he is inclined to form ideas for himself which are not always of the best; and it is then frequently necessary to do more than to invite him to accept reforms. The upper classes of Europeans are similar to European colonists found elsewhere; with this exception, that they take less patriotic interest in Egyptian affairs than they would if they were living in a colony of their own country. The low-class Europeans, the low-class Greeks or Italians, who form a large percentage of the population, are a very difficult community to deal with, and the Levantines may be regarded as being neither native nor low-class European.

A brief consideration of the Government of Egypt and the laws in force regarding sanitation is necessary. The identical Government of Egypt is complex. Egypt is Turkish territory, ruled by His Highness, the Khedive. There is a Council of Ministers, and the interests of European subjects are safeguarded by the Consuls-General and Consuls. Laws which affect natives can be passed by the Council, but important measures which affect Europeans have to be sanctioned by the country or countries concerned.

The British Agent has under him several British officials who are supposed to act as advisers to the native ministers, but who, in reality and quite openly, have charge of the several Government Departments. He is practically the autocrat of the country.

The only laws with which we are immediately concerned are those which govern sanitation, and they are few in number.
The Government is under a difficulty with regard to this because, although they can be enforced with the native, the procedure with Europeans is more difficult owing to the "Capitulations." In the event of epidemics of certain specified diseases, such as plague, cholera, etc., stringent measures can be adopted with reference to native individuals and habitations. In the case of Europeans, however, it is necessary to invoke the cooperation of their Consuls, which involves delay. There is a sort of Capitulation Act which is applicable to natives and Europeans alike; it necessitates the passing by the Government of the plans of new "unhealthy establishments," and it allows existing ones to be inspected. Unfortunately, this measure is very elaborate, not well suited to the conditions found in Egypt, and usually considered almost to be unworkable by the inadequate staff at the disposal of the Director-General of the Public Health Department. The native and Levantine are so cunning that they succeed frequently—and it speaks from personal experience—in evading this law; and the punishments, especially those given in the mixed courts to Europeans, are so lenient that it often pays the individual to ignore the law and suffer the small penalty.

So far as sanitation is concerned, the Capitulations enjoin that no official may enter the house or property of a European subject unless he has obtained permission either from the subject himself or from his Consul. In considering all sanitary reforms, this has to be taken into account; the Consuls sometimes, though not often, are unwilling to assist, and officials in Egypt usually complain that the Capitulations obstruct their efforts. In fact, this has become a tradition, and if any new effort fails, the Capitulations are usually blamed. There can be no doubt that the measure is an obstacle, though not such a serious one as is made out, and to this point I shall again refer.

Other questions will be mentioned in the description of the several campaigns, which will now be taken seriatim, in the order in which they were started.
ISMAILIA—At the present day Ismailia is a sleepy little town picturesquely situated on the shores of Lake Timsah. De Lesseps intended it to be one of the greatest ports in the world. When the Suez Canal was opened, and the venture an assured success, it was determined to make Ismailia a model city, a thriving port, and the headquarters of the Suez Canal Company. With this end in view, the Company acquired the control of a large piece of land on the northern shore of Lake Timsah, a small sea-water lake through which the canal passes, placed in the centre of the isthmus of Suez. There the offices of the Company were built, surrounded by the houses of its employees, and the largest shareholder, the Khedive Ismail Pasha, built himself a magnificent palace. Villas were erected overlook- ing the Canal and gardens were planned and parks marked out. All the ships in transit of the Canal stopped there, and passengers were to land, and carry to Egypt was transported. Then there was boating, bathing free from sharks, boating, and every indulgence both for work and play. Ismailia, though young, was very healthy, being situated in the desert and isolated from other towns. It was completely under the control of the Company, who spared no expense to make it a model town free from unsanitary native huts or unsightly modern flats and hotels. The Government offices of the district were situated there, with the Courts, and the town soon began to prosper. De Lesseps' intention was on the highroad to fulfillment when, owing to ignorance, a false step was made.

The town was supplied with fresh water by a shallow canal which connected it with the Nile. The canal was built in 1872, and replaced the old system of transport of water by canal, which was in vogue during the early years of the Suez Canal construction. The water in this canal, which was deepened in 1882 to allow the passage of canal boats trading between Cairo and Ismailia, was laden with a rich silt from Abyssinia, and it was used to irrigate the desert and the marked-out parks and
gardens, with the result that a veritable oasis was formed. Trees were planted, and the gardens grew apace under the influence of the irrigation. But the water was not properly controlled, and much of it ran to waste, forming shallow marshes and pools in and about the town. With the marshes came the mosquitoes; and with the mosquitoes came the fever; and with the fever came the—downfall. In the days of its salubrity, Ismailia had progressed very rapidly, rising to a population of 30,000, but when the fever appeared, all progress stopped and decadence took its place. Nearly 2,500 cases of malaria were treated every year, but probably many more occurred. Men, both European and natives, were unable to work, children were always ill, the death-rate increased, while the birth-rate fell. Every one was down with fever, and trade was at a standstill. The Government offices were closed and were ultimately moved to Port Said; the tribunals were transferred to the neighboring towns of Zagazig and Munsrah, and the Suez Canal Company were, in 1900, left to face the question whether the town should be abandoned, or whether the disease could be prevented.

In 1877, when malaria first appeared in Ismailia, 300 cases occurred from August to December. The next year there were 400 cases; and the annual sickness remained at about this figure until 1891. The disease then became worse, and in 1891 nearly 2,500 cases were recorded. Acting on the assumption that the disease is caused by a miasm, the Canal Company made several efforts to combat it by partially draining the marshes, and probably these efforts prevented the epidemic reaching extreme dimensions. The discovery of the transmission of malaria by mosquitoes was not completed until 1899. In 1902 the Company resolved to take further advice. They sent a medical officer to Italy to make enquiries about the anti-mosquito measures being conducted there, and then they invited my brother, Major Ross, to go to Ismailia to advise them. He arrived at the Suez Canal on 12th September 1902,
in company with Sir William McGregor, the Governor of Egypt, who wished to study the malaria at Ismailia with him.

1 The first measure to be recommended by Major Ross was the extermination of mosquitoes, which was immediately put into effect. The Company bearing the entire expense. The

main breeding-places for mosquitoes were found to be shallow irrigation pools and paddies in the gardens and parks, where Anopheline larvae were taken. Each house has its crevices, according to the general rule in Egypt, for there are no properly instituted sewage arrangements in the country, and all sewage passes directly into the "fouls," under the house. The fresh water canal, which brings drinking water from the Nile and which passes through the town, does not harbor mosquitoes. Then the water is running, and fish are plentiful; let a short distance away from the town a marsh was formed by leakage from the canal, and here larvae were found. Rigorous measures were adopted; the marsh was drained and the pools were filled up. A mosquito brigade was formed, which consisted of a European foreman and two natives. Their duty was to visit every house once a week, and to treat the cesspools with petroleum. Irrigation canals and channels were cleared of mud, and the water made to flow swiftly. When a certain garden had received its proper supply of water, the flow was stopped and the water allowed to soak in. All the work was systematic; each breeding-place was visited and treated on a certain day in each week, which was kept up throughout the year. Similarly, all water vessels, tubs, and flower vases were emptied. A penalty was imposed on the inhabitants if they did not report untreated collections of water to the authorities. No expense was spared to make the new sanitary measure a success.

There is one difference between the Ismailia campaign and the others which must be mentioned. The Capitulations did not form an obstacle there. The laws at Ismailia were the same as those elsewhere, but the Canal Company made short work of the Capitulations, for practically all the inhabitants, whether
European or native, were employees of, or dependent on the Company, and if they objected to the visits of the brigade they could be either dismissed or have their salaries cut.

Instituted by their President, Prince d'Arenberg, the Sue Canal Company can justly be proud of the result of the anti-mosquito work at Ismailia. Last year not a single new case of malaria occurred there, and the disease has been stamped out.

Ismailia affords a striking example of the great commercial importance of malaria prevention. When De Lesseps decided that the headquarters of the Canal should be at Ismailia, he, of course, did not appreciate the possibility of invasion by malaria. I believe that his decision was due to the presence of the large natural harbour afforded by Lake Timsah, where a fleet of ships could anchor to take in coal and provisions on their way through the Canal, without obstructing the transit of other ships. It is true that all coal has to be imported from Europe, but in spite of the fact that Ismailia is nearly 50 miles from the Mediterranean, the presence of the natural harbour there was so important, that the extra expense which would have to be incurred in bringing the coal through the 50 miles of canal was hardly taken into consideration. In fact it paid the Canal Company to insist on all coal being brought to Ismailia, because dues were obtained for its transit. Commercially, everything was in favour of Ismailia being made the headquarters of the Canal. The point is an interesting one; for De Lesseps' great commercial proposal was disposed of by malaria. For years the Company tried to force ships to coal and land passengers at the fever-stricken town, but now they have been compelled to relinquish the natural harbour, and to build an artificial one at Port Said (which requires, and always will require, incessant dredging) at an outlay of many millions. Even natural assets of enormous commercial value, such as this harbour in the greatest shipping highway of the world, fall utterly in the face of a comparatively small epidemic of malaria. The artificial harbour at Port Said has been built, and Ismailia has dwindled.
The results of the anti-malaria work are well known. Accurate figures, showing the number of severe cases of malaria which had occurred before the mosquito work was started, had been kept, and these could be compared with those obtained afterwards. Every employee of the Company is obliged to go to a doctor when ill in order to obtain a certificate of absence, so that all cases were easily recorded. But there must have been a number of cases of early and slight fever, in which the malaria parasite would not be in evidence, and which would not necessitate the patient lying up; and besides, there were those cases which occurred in persons who were not employed by the Company, and also many native women and children, who will not go to doctors. But the results which are given by Dr. Prout are very interesting.

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<td>250</td>
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And now, although cases of malaria are occasionally introduced into the town from the villages situated higher up the fresh-water canal, such as Mahsammah, Nefiche, and Tel el Kebir, yet the disease never spreads there because the Anophelines are absent, and there is no longer any necessity for taking quinine.

The chief difficulty and source of expense at Ismailia was that of the initial control of the irrigation, and the drainage...
filling up of the marshes which surrounded the town. And even now, in the autumn, mosquitos find their way there from marshes situated to the west above the town, these being the habitations between. These marshes would cost much to drain or fill—an unnecessary expense. The number of mosquitos introduced into the town from this source is so small that it may well be ignored, and there is but little chance of their becoming infected, as there are now no cases of fever in the town.

The cost of the permanent works, including the filling up with sand and the draining of the marshes, ponds, and the control of the irrigation, was 500,000 francs (£300).

The annual cost of the regular work of clearing streams, ponds, and of keeping the gardens clean of mosquito larvae is 7,800 francs. And the oiling of the cesspools and the general work of the mosquito brigade is 10,700 francs. Of this sum, 5,300 francs are spent annually on oil, and 5,200 francs on salaries and other incidental expenses. Thus the cost of the regular annual work is now a franc 30 centimes per head of population per year; at first it was 3 francs 30 centimes. The total annual cost is now about £1,000 per year. And for this sum, after an original outlay of £2,000, Ismailia is kept healthy and free from fever.

But the work must always be kept up, though the cost of it will gradually decrease. As in Port Said, if the mosquito brigade stops work for a week, the mosquitos return. The men require constant supervision. M. Doyen, of the Suez Canal Company, is to be heartily congratulated on the way the work progresses, for the town continues free from malaria.

But Ismailia has never recovered the blow that malaria dealt it, for natives now call it "El Turba' ebn Awa" (the clean tomb). Port Said—Port Said was a much more difficult problem than Ismailia. The town is larger, with a very cosmopolitan population of 50,000 inhabitants. It is built on a triangular spit of land bordered by the Mediterranean, the Suez Canal, and the shallow sea-water lake of Menzalah. The price of
Port Said may be said to be built on a sand bank. All the drainage from the houses passes into cesspools, usually placed under the floor. Owing to the height of the subsoil water, these cesspools are frequently too small to be adequate, and overflow as a common result. They are continually being emptied at great expense, which falls on the landlords, who are not too willing to carry out this duty. It may be imagined, therefore, that before the mosquito campaign was started, that is, before any proper systematic sanitary administration was instituted, Port Said was one of the most insanitary places. Many of the houses had basements, and the cesspools were bricked over and built into the rooms, contained in them. When the cesspools became full, they frequently burst, and the sewage passed into the rooms which formed the basement. I have often seen shops and dwellings, with only a wooden flooring separating the living rooms from the sewage, and more than occasionally one used to see persons living in a room with the sewage coming up through the floor. Without exaggeration, one can say that a few years ago Port Said was famed for being one of the most disgusting "holes" on the face of the earth. Crime was rife, every one looked ill, and it was openly said that all the scoundrels in the world collected there. In fact, little more than ten years ago it was hardly safe to walk in the streets at night. The population is largely European, to a far greater proportion than in most other Egyptian cities, and owing to the Capitulations, the Government police officials could not enter the European houses, and knew little of what was going on.

But the filth and general insanitation were almost indescribable. Sewage used frequently to be seen trickling down the pavements from the overflowing cesspools, and puddles of
local matter found in the roads. Sometimes the stench was so strong that certain houses and corners were deliberately avoided by pedestrians. Mosquitoes bred in the sewage and then bit the inhabitants. The authorities could do little or nothing owing to the Capitulations (so they said). Clearance would be approached by means of endless correspondence and red tape. Sometimes a little improvement was effected, but usually nothing was done. Fever was rife and mortality very high. It was dangerous then, as it is now, to keep a European child in Port Said during the summer months. I have seen an infant's face so covered with mosquito bites that I thought it was suffering from confluent small-pox. The whole place was a 'snitch of iniquity,' a statement which, I think, will be confirmed by any person who passed through the Suez Canal a few years ago.

But the mosquito campaign has changed all that. Practically speaking, the Capitulations have vanished. Sanitary inspectors, on the plea of mosquito destruction, now enter every house, and every dwelling-room if necessary, in the town. Everything is known and reported to the police should occasion require it. And the remarkable thing is that no one appreciates this reform more than the Europeans themselves, even the lowest class Levantine. Children are healthy, trade has increased, and crime and vice have been reduced to a minimum. In fact, Port Said now resembles a quiet seaside watering place.

The history of the reform—and it is well worth recording—is a remarkable one. Towards the end of 1905 my brother, E. H. Ross, then a surgeon in the British Navy, was appointed Medical Officer of Health to the town by Sir Horace Pinching, the Director-General of the Public Health Department. The new officer, appreciating the results obtained at Ismailia, owing to the advice of our brother, E. Ross, saw that similar measures would effect far greater results at Port Said. It was true that there was no epidemic of malaria as at Ismailia, but Anophelines had been found in many places, and malaria did undoubtedly occur. Culex pharaonis and Anopheles maculipennis...
Fort Said.

[Excerpt from the text]

Forts both malaria-propagating mosquitoes were found breeding in puddles and reservoirs. Moreover, the ubiquitous 

[Further text]

In Port Said, only those who lived in the town before 1900 can realise the misery caused by this pest. Quite apart from the fever, the constant irritation of the mosquito-bites, and the persistent manner with which the insects used to attack one, both during the day and night, nearly drove one mad. I have seen clerks in offices arranging mosquito-cots over their desks in the daytime, hanging them on to the gas brackets, and the native workmen in factories covering their naked feet and legs in paper to prevent themselves being bitten. A certain amount of immunity against the irritation is produced in time, and certain individuals feel the effects of the venom less than others, but they are bitten for all that. Then the heat of the mosquito-net at night. Every time one moved in one's sleep, and threw off any bed-clothes that the heat would allow, one was liable to touch the net with a hand, arm or leg, and to be bitten through the net. And the persistent scratching and the disturbed sleep—these things have to be experienced to be realised. I have estimated that a mosquito-net makes a difference of three degrees Fahrenheit when there is any wind. And if there is not any air that there is. How well I remember the many evenings sitting at the laboratory table, trying to dissect mosquitoes, trying to investigate their internal economy, while they in their turn were doing their utmost to investigate mine, nibbling my ankles, raising wheals on my wrists, and neck, and making all work impossible. At all events I think that they had the best of the bargain. And then, too often, in a fit of rage one has chased them with a fly-whisk, or stalked them with a candle, making oneself hot with the exertion of numerous futile attempts, until driven to the refuge of the mosquito-net, hot and in a bad temper.

It was clear that, in spite of the possibility of there not being very much malaria at Port Said, the general prevalence of mosquitoes probably caused illness, and my brother grasped that an attempt at their destruction could only bring good results and might lead to the general clearing up of the town.
He therefore made enquiries as to how much fever there was which could be attributed to mosquitoes. Formerly, a fever of mild type, which used to affect whole households and which lasted for two or three days, was common in Port Said; sometimes it was called dengue and sometimes influenza. Quinine was beneficial in some cases. Malaria did occur, a fact which was proved by Dr Cuffey, the Medical Officer of the English Hospital. Anaemias were sought for and found, but not in very great numbers, although they were breeding in many parts of the town. An examination of 50 children showed that 10 were suffering from anaemia and splenic enlargement, and out of 156 children examined in the hospital wards, 10 were found with malarial cachexia.

Dengue was also prevalent, and came in epidemics from other parts of Egypt. This disease is said to be conveyed by Culex fatigans, which is a very common mosquito throughout Egypt. Then there was the disease known as Simple Continuous Fever, which seems to infect schools and factories.

Unfortunately, there were no reliable statistics. Diseases are supposed to be notified in Egypt, but doctors do not obey the regulation, which is not properly enforced. Natives do not usually consult doctors, and patients are frequently not seen until death. The Public Health Department thinks that a cursory examination of a dead body, with a rough speculation of the disease from which the person suffered, is sufficient to form an idea of the diseases prevalent in Egypt. Statistics are published, but they are quite worthless; the only reliable data therefore, are the number of registered deaths. In 1904 the number was 1,412; in 1905, 1,308; in 1906, 1,199; and in 1907, 1,412. The actual population was unknown, and although a census has been taken recently, it is not accurate. The absence of reliable figures is the most unsatisfactory part of anti-mosquito work in Egypt, except at Ismailia.

As in subsequent campaigns, two steps were necessary at the outset: to estimate the cost and obtain the necessary funds.
and to arrange a scheme to overcome the "quarrels." To estimate the cost a house-to-house examination was made. It
was decided to treat only the European quarter, which
lies to the east of, and is distinct from, the native quarter.

The European quarter was chosen because it contained more
mosquitoes, and if the work was successful it would be a
good example to the native quarters, especially the Mamelous,
who are suspicious of innovation. Moreover, this was the first
campaign in which the "quarrels" formed a difficulty, and
the starting of the campaign in the European quarter formed
an experiment which demonstrated how effectively that
difficulty could be overcome. It was thought that if the campaign
were started in the European quarter, it would be easier to
surmount the "quarrels," and the European quarter was
chosen as the starting point for the "quarrel" campaign in
Port Said, in showing how easily this obstacle to success

European quarters were visited intermittently. Studies
were made, and the number of mosquitoes in water depres-
sions, such as mosquitoes breeding in oil-lamps, basins, water
holes, etc., was noted, with a note as to the number of square
metres of water surface they contained. The number of days required to make
this examination from east to west and from north to south by one
person was also noted, and then an allowance of half a litre of mixed equal parts of oil
and insecticide was allowed for each square metre of water surface per week. This gave
the amount of oil required to destroy the mosquitoes breeding in all the
water in the town every week, and the estimate was therefore multiplied by fifty-two,
so the work was to be repeated every week during the year, with mosquitoes breeding during the
winter as well as during the summer months. Then by a simple calculation it was determined that it would require a point of
workmen, containing five men under the charge of a foreman,
to apply the oil to all permanent accumulations of water in the
European quarter every week; and therefore one mosquito
brigade would be required to get rid of the mosquitoes in this
part of the town. The price of oil in Port Said is as follows —
The purchase of refined oil in tins containing 18 litres (4 gallons) is 8 piastres per tin, and refined oil is 11.3 piastres per tin. To the cost of the amount of oil required per year, then, it was necessary to add the yearly wages of the five workmen at 6 piastres per day (1S. 3d.), and the foreman at L.E. 5 per month. The purchase of an oil barrel on which five buckets, five half-litre tin measures, 15 barrels for each workmen, and allowing for small repairs to the equipment, etc., the estimate of the cost of the campaign in the European quarter was obtained per year. The estimate amounted to L.E. 800, but the actual cost for the first year was L.E. 789 (L.E. about 3 shillings). The estimate had been made and the money subscribed, and it remained only to obtain the necessary official permission to enter the houses of all foreign subjects from the various consuls, so that the work would not be hindered by the domicile clause of the Constitution. In order to obtain this permission, we advertised in every direction, spoke to all influential persons and made people interested, and then when the Government wrote officially to all the consuls, they unanimously consented to assist us in every way, and gave the sanitary authority of the town permission to enter the houses of their subjects for the purpose of disinfection and for killing mosquitoes; and each consul appointed a prominent member of his community, to whom any difficulty could be referred without officially disturbing the consular delegates. We, on our part, undertook to supervise the work carefully, as the workmen had to enter every house once every week, and to take all reasonable precautions to ensure their honesty. And in this respect it is noteworthy that although the work has now been in progress without interruption for three years, there has not been a single charge of dishonesty upheld against the workmen, nor has there ever been occasion to appeal to the consular delegates.

The preliminaries had taken two months, but everything was ready for a start early in May 1906. Many good authorities had said that it would be found impossible to clear the town, or a portion of it, of the mosquitoes which infested it; even as they say that it will be impossible to clear Cairo today, but it was determined to try. A gang of five men were engaged. They were all natives of good character who lived in and had families in the town. A Greek foreman was found who could speak all the necessary languages, which include Arabic, English, French, Italian, Greek and Turkish. An iron barrel, capable of holding 300 litres, fitted to wheels to enable it to be pushed about the streets, was bought, and each workman was given a bucket, a half-litre measure, and a brown-stick,
while the sweeper was armed with a notebook. This was the equipment for the European quarter, and the following routine was initiated. The quarter was subdivided into six equal portions, one for each weekday. Work begins every Monday morning at the Governor's house, and one member of the brigade visits every house allotted to him that day. Every house is remembered, and is placed in the charge of one workman, who is responsible for the inspection, and the absence of them, in that house. On Tuesday morning, at seven o'clock, the brigade begins where it left off on the Monday evening, and so on, until the whole of the part of the town is completed by Saturday night at the Governor's house again. Thus, every house in the quarter is visited by the same workman at the same hour of the same day, and the tenants know when to expect him, and can complain to the house of his absence regularly. Each workman fills his bucket with mixed crude and refined oil from the oil-cart in the street. When he arrives at the house allotted to him he asks the tenants if they have been annoyed by mosquitoes during the week. If the answer is in the negative, he enters the house with their permission, and pours a small quantity of oil down each water-closet and sink. He mounts to the roof, where in Port Said the wash-houses are usually situated, and empties out all tubes and basins containing water. He examines the kitchens and servants' rooms in each flat, for any collection of water which they may contain. Householders are now only used to this weekly visit, for the men are well known, and it serves to remind the tenants to see that the workmen carry out his duties properly, and at the same time they are advised to empty out all water which mosquitoes are likely to breed, as in flower-pots and in sundry utensils. The workman then descends to the basement, where he examines carefully every cellar for any water or sewage; and he then opens the cistern of the building and pours into it that amount of oil allowing ten, after these years, a quarter of a litre for each square metre of water surface it contains, or nearly as possible. The oil on the surface of the cistern water is then well-stored with the benevol-stick, so that it may spread everywhere evenly. Lastly, he walks the gardens and examines the fountains and the water-taps, bucket-pots, and the plants if there is one; and, when finished, he goes on to the next house allotted to him, repeating the process while refilling his bucket from the oil-cart in the street.

* In Port Said, as everywhere else, there is no method of flushing the wash-houses, as in the filtered water systems in the United States. We have therefore been told to give them money.
But should the tenants complain of the presence of mosquitoes and the workman find that the cesspool is full, or that the cellars contain water, he at once informs the foreman, and they both begin a careful search for the mosquito larvae. The foreman reports at the Public Health Office every morning at noon, and details the presence of mosquitoes, and whether the larvae have been found or not. He also reports on the sanitary condition of the streets dealt with, and the houses examined that day, and states whether any cesspool requires pumping out, or whether any cellar has water in it, in which case the proprietor of the house is dealt with by the Sanitary Inspector, and an extra foreman is sent down to find the mosquito larvae, when they cannot be found by the brigade.

Ultimately, when the mosquito larvae have been found—and they can always be discovered if carefully sought after, either in the house itself or on the premises—they are put into a bottle and examined. If there are any mosquitoes, it is known that the eggs have been laid for more than seven days, and therefore the workman responsible for the house has neglected to oil the water in which they were found, and he is punished. But more often it is found that the proprietor of the house is at fault, and the mosquitoes have reappeared because he has neglected to have the cesspool pumped out; and in consequence of its being full it has overflowed or has burst, and the sewage has collected in the cellars, and there the mosquitoes were breeding. In this case the proprietor is written to and is warned to empty the cesspool without delay; or he will be sued and fined in the Courts; for there is a law which enables us to do this. Every cesspool in the town has been fitted with a movable iron door, so that access can be obtained to its interior when desired. We persuaded the proprietors of all the houses to put these in, for we found that there are some cesspools into the farthest corners of which the oil cannot reach when poured in through the water-closets and sinks, or even through the door. This is probably due to solid sewage floating on the surface of the water and preventing the oil spreading evenly. In such places the oil is well stirred with a broomstick to make it reach all parts; but if this fails also, then we have had recourse to the automatic oilers described in the *Annals of Tropical Medicine* for June 1907, and they have been most successful for the purpose, though even when these are in use the cesspools containing them must be carefully examined every week in case the oil becomes clogged. This is recognised by the presence of male and female mosquitoes in the cesspool after ten days have passed since the clogging.
This is the routine which has been followed ever since its institution in the European quarter, and which has been copied exactly in the native quarter. It has undergone no modification, except that the amount of oil used weekly has now been reduced considerably.

The work in the European quarter was begun in the first week in May 1906, and by the end of July, the mosquitos in this part of the town were sensibly diminished. The summer was very hot and damp but we were able to rest in the afternoons without being bitten by Stegomyia. By the end of August mosquitos had been reduced greatly; and in many parts of the European quarter mosquitos were no longer required. But it was found that we were using an enormous amount of oil, nearly 3000 gallon of equal parts crude and refined oil per month. This was because of the sewage in the cellars. It was therefore determined to try to reduce the amount of water in these cellars permanently, so as to economise the oil. There were then 400 cellars in the town flooded with sewage, having a total of 7,296 square metres water surface.

This condition of insanitation was due to the following peculiarity of the place. The subsoil water (sea-water) is only a metre below the ground-level, as the whole spit of sand, on which Port Said is built, is reclaimed from the sea. Owing to the small area reclaimed, the ground rent is very high, and in consequence many large buildings, of often four and five and even six stories, have been erected, and divided into flats and suites of offices. These houses have been built with basement cellars. In every building the portion of the cellars situated under the main entrance hall has been shut off by brick walls from the cellars to form the cesspool, into which all the house drains discharge. These cesspools were supposed to be sealed except for a ventilating shaft, but were, in the majority of instances, badly built and leaky. The result was that the sewage was passing into the adjoining basement cellars as fast as it poured into the cesspool. Once in the cellars it did not rapidly soak into the sand forming their floor, as at that level the sand was already saturated with the subsoil water. So that we found when we began our campaign, that in the 400 large buildings the whole basement constituted the cesspool, and in them mosquitos, flies, cockroaches, and other insects were breeding in myriads. These cellars were also swarming with rats and were the cause of the perpetual smell of sewage which assailed one even in the street.

Towards the end of 1906, people in the European quarter 2 in.
were beginning to discard their mosquito curtains and life was becoming more bearable, and, as was anticipated, the natives began to ask why their quarter was not treated also. In response to their request, therefore, a campaign was started in the native quarter in January 1907. A fresh brigade was formed, and the campaign was conducted on precisely similar lines to that in the European quarter.

The results at Port Said have fully compensated for the cost of the undertaking. When I was in Port Said for seven months in the spring of 1908, I never saw a single mosquito—a marvellous contrast to my experience in the same town ten years before. Mosquito curtains are never used now by the inhabitants, and no precautions whatever are required to be taken against being bitten.

The following table gives the cost of the campaign, the Egyptian Pound being equivalent to about twenty-one shillings.

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount of oil used</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906 European quarter only, May to December</td>
<td>1,206 gallons.</td>
<td>L.E.137.96</td>
</tr>
<tr>
<td>1907 European and native quarters for the whole year</td>
<td>4,120 gallons.</td>
<td>L.E.1,166.275</td>
</tr>
<tr>
<td>1908 both quarters, 12 months</td>
<td>31,670 gallons.</td>
<td>L.E.1,063.43</td>
</tr>
</tbody>
</table>

It will be noticed that the amount of oil used, and therefore the cost of the work, diminishes every year, and this should be expected. Should the present cesspool system of sewage disposal ever be replaced by drainage, the amount of oil required will become very small, and the size of the gangs could be reduced, for there would be less work to be done.

But the cost of the campaign has been trifling compared with the beneficial results to the community. Everybody has been delighted with the results, fevers have declined, and the children have become healthy. The streets no longer smell as they did, and the place has improved in every way. The

1 In 1902 Sir W. MacGregor and I were "devoured alive" by Stomoxys in Port Said. During three visits in 1907 and 1908 I did not see a single mosquito—R. Ross.
absolute disappearance of mosquitos is a most remarkable thing, and is probably unique in history; yet if the brigades become slack, the gnats reappear in a few days. The inhabitants now complain at once if mosquitos appear, and their breeding-places are then looked for. They will always be found in the immediate neighbourhood.

But the general effect on the town is the most striking example of the efficacy of the sanitary measure. Officials of the Government enter every house unmolested; they know all that is going on, and, in consequence, vice has been greatly reduced. Port Said is no longer a "sink of iniquity." The streets are safe; there is less prostitution there than in any town in Egypt; gambling dens have disappeared; all is known in spite of the Capitulations. If a cesspool bursts or overflows, the landlord has to remedy the defect, or he has to stand the abuse of his tenants owing to the return of the mosquitos. Moreover, he is promptly sued by the Government. The consuls themselves, far from obstructing, now assist the authorities in every way.

It is right to mention that the Suez Canal Company, through its President, Prince d'Arenberg, have placed a large sum of money for the maintenance of this campaign at the disposal of the Egyptian Government.

This campaign at Port Said is perhaps the most successful which has ever been started, and any one who is able to compare Port Said in the old days with the present state of affairs will, I am sure, eulogise the work which has been done. A great deal remains to be done, however; but the mosquito campaign has paved the way for it, and has shown that with a little perseverance sanitary reform in Egypt is not nearly so difficult as is usually made out.

There can be no question this drainage is the next thing required at Port Said. The present cesspool system is quite inadequate, and it should be replaced by proper sewerage as quickly as possible. A scheme has been drawn up and passed,
I believe; and I have heard that the Suez Canal Company have offered to advance the necessary funds for it. It is difficult to appreciate, therefore, why it has not been undertaken. The Egyptian Government itself appears to be doing very little for Port Said, but the least it might do is to accept the Canal Company's offer and drain the town. At present negotiations are on foot between the Government and the Company regarding the latter's concession, and I suppose that the health of Port Said has suffered for this delay. The drainage will be expensive, for it will have to be done on the artificial pumping system, there being no "fall" at Port Said. Still, drainage there is almost more necessary than at Cairo. If the place were properly drained, the expenses attached to the mosquito campaign would be reduced almost to a negligible quantity.

Cairo.—Cairo is a very much larger city than Port Said. It contains an estimated population of more than half a million, the European element being smaller than that of either Port Said or Alexandria. The town is situated on the east bank of the Nile, at the apex of the delta of the river. Facing Cairo, on the other side of the river, there is the town of Ghizeh; and between the two, on an island, there is the residential suburb of Ghezireh. Cairo proper can almost be divided into two portions—the native to the east and the European to the west—by the old canal, now filled in to form a tramway, called the Khalig. Suburbs extend to the north and south, but the city itself is compact, and, for its population, does not cover a very great area. Owing to the fact that the Government owns most of the surrounding land and will not part with it cheaply, the price of land is exorbitant, and in consequence there is great overcrowding, with the erection of high buildings containing residential flats (in this city, with its almost tropical climate).

Cairo is infested with mosquitoes. To destroy them throughout the city would be a stupendous, but not impossible, task, and it would involve an expenditure of about £20,000 annually.
It is true that in the winter months the gnats are not so numerous, but in the summer and autumn the pest is as bad as in many tropical places.

Like Port Said, Cairo is built on a lake of subsoil water. The Nile water, of course, is not confined between the banks of the river. In fact, the underground river is much larger than the Nile itself, and it flows directly beneath the city of Cairo. The height of the subsoil water, therefore, varies with the height of the Nile, and in the months of September and October, when the Nile at Cairo is in flood, it frequently happens that the basements of the houses are filled with water.

Every house, native or European, has its cesspool, which leads directly into the subsoil water; and for centuries past all the sewage of the city has passed directly into this underground lake and has saturated the soil all round. The cesspools of the houses built by Europeans are called "percolating pits." They are commonly built immediately beneath the houses, and they vary in size according to the uses put to them. Their bases are deficient in bricks and are formed by the porous earth only. Every cesspool dips into the subsoil water, and bricks are removed from the walls in places to facilitate the percolation of the sewage into the surrounding earth. It can veritably be said that the land on which Cairo is built is sodden with sewage. Nearly all the pits are ventilated by short intake and long uptake shafts carried up to the roofs of the houses, and it is by means of these pipes that mosquitoes gain access to the cesspools. A few of the more modern houses are fitted with "fosses morasses," which are, in reality, modified liquefying tanks. Some of them are made on a fairly satisfactory basis, but usually they are pretences, and are nothing more than rather elaborate percolating pits.

The native cesspool is, if possible, more insanitary. It consists of a long trough dug in the earth under the house. Stone flags form its roof, and one of these flags, having a hole
in it, is used as the closet. No water flushing arrangement is employed, and fluid soon seeps into the earth. For this reason mosquitoes do not breed so readily in the native as in the European cesspools, and consequently they are not so numerous in the native as in the European quarter of the city.

Both classes of cesspool have to be pumped out from time to time, and conservancy carts form an important, if not an ornamental, portion of the Cairo traffic. The pumping out process is an expensive item for the landlord, and is a lucrative business conducted, not by the Government, but by private enterprise. On the plea of expense landlords frequently neglect to cause the cesspools to be emptied until the last moment. At present there are no drains. For the last three years the Government has made a special drainage department for the construction of sewersage. I have heard that the plans of the scheme have already been passed. In the meantime, when the soil is turned up in any part of the town for the purpose of making the foundations of new buildings, the stench is usually indescribable, for the subsoil water is soon reached, and that water is practically sewage. Moreover, these excavations form fruitful breeding-places for mosquitoes.

The water-supply of Cairo is derived from shallow wells placed below the town, a source which has given rise to considerable controversy. In the native quarters, almost every house has its own well, which is bored close beside the porous cesspool. The water in the well is that which has usually percolated in from the neighbouring cesspit. The natives prefer this or the Nile water, which, of course, is polluted, to that supplied from the wells at Rod el Farag. When cholera broke out some years ago, many of the wells were filled up, but they have nearly all been reopened. In all the cesspools, wells and other collections of water which riddle the city, mosquitoes, cockroaches, and all sorts of vermin thrive. The human mortality is enormous, especially the infantile mortality. The figures supplied by the Public Health Department are
unreliable (as I know, for I have assisted to compile some of them). The actual population is unknown, many deaths are probably never reported, and sickness is not usually notified. All deaths are supposed to be registered, the diagnosis usually being made by a brief inspection of the dead body. Doctors will not notify disease, because they say that it ruins their practice. Landlords prefer to knock holes in the sides of their cesspools and allow the sewage to flood their cellars and basements rather than to go to the expense of having them pumped out. The water-supply is not the best obtainable, the streets are not properly cleaned, and enormous heaps of dung and rubbish have been allowed to accumulate for years past on the outskirts of the city. Many of the streets are not metalled; which perhaps is a good thing, for the rough surface acts as a sponge for the stale urine which would otherwise collect in puddles. Dung and street refuse are used as fuel generally; and large collections of this rubbish are kept for this purpose on the roofs of the "Turkish Baths." Nearly all the dogs have been destroyed owing to outbreaks of rabies, and many cats have taken their place as natural scavengers. Hordes of flies, which breed in the dung and rubbish, abound everywhere, and are nearly as great a nuisance as the mosquitoes. Without exaggeration, Cairo may be described as a city which is hardly fit for habitation, and at present it must rank with Moscow, Pekin and Hankow as being one of the most insanitary spots in the world. Since the mosquito campaign, Port Said is a health resort compared with it.

The common mosquitoes found are Culex fatigans, Sabethes fasciata, and a species of Asthenus called Cella flavescens. They breed in the cesspools, wells and ornamental fountains. The natives love fountains, and their houses always contain large numbers of water vessels of all sorts and sizes. Fevers are undoubtedly rife. Typhoid broke out in one or more of the principal hotels each season when I was in Cairo; for it must be remembered that Cairo is a favourite
MOSQUITO REDUCTION IN EGYPT

The typhoid is probably propagated by the vegetables, which are usually washed in old canals, or even cesspools, by the natives when they bring them into the town. Some years ago a scheme was made to prevent this washing, which is done to make the vegetables glisten and look fresh for the market; but the Government would not adopt it. Dengue, which is probably propagated by Culex pipiens, occurs in epidemic form every year. Malaria exists in Cairo, but it is only of the mild tertian and quartan types. Following some questions which were asked in the House of Commons last year, a controversy arose in the Press in Egypt regarding the incidence of the disease. One paper said that it did not exist. But it does. Only last summer an outbreak occurred at Ghezireh, and according to the Statistical Report of the Public Health Department for 1908, twenty-nine deaths occurred in Cairo alone from the disease. The Senior Medical Officer of the Egyptian Army reported an outbreak at Zeitoun and Abbassieh (suburbs of Cairo) on 3rd November 1907 (Letter No. 411). I have myself seen cases of malaria, and have taken Anophelines frequently, especially at Ghezireh. Probably the incidence of the disease is far greater than is commonly supposed. Several other diseases, such as Simple Continued Fever, are confounded with it. Elephantiasis, also conveyed by Culicines, is a common complaint, and victims are frequently seen begging in the streets.

A real estimate of the incidence of malaria has never been made. Last year a small spleen census was taken among some children, but the result was vitiated by the discovery of a disease, provisionally called "Endemic Cirrhosis of the Liver," which occurs among them. Still, malaria exists, and other fevers too; which is sufficient ground for the institution of a campaign, apart from the other great sanitary benefits conferred by these undertakings. At one of the campaigns, that at the Police School, figures have been obtained.
which I shall quote later, and they demonstrate amply the beneficial results which would accrue from general mosquito reduction. Cairo is visited annually by thousands of English and American tourists, who live in palatial hotels, and who cannot realise the real state of affairs. From a superficial visit, Cairo is a most picturesque city; but let them go off the beaten tracks into the depths of Boulac, Saida Zenab, and Bab el Sharia, districts which visitors do not often see, and they will then appreciate the insanitary precipice whose brink they visit.

The first mosquito campaign in Cairo was started by a few English residents in the district of Kasr el Dubarra in 1904 or 1905. Only a few houses were treated (by the residents themselves), and although a reduction in the number of mosquitoes resulted, the campaign soon lapsed owing to the fact that many of the breeding places were overlooked. In the meantime, Sir Horace Pinching, K.C.M.G., Director-General of the Egyptian Public Health Department, who was very pleased with the work of my brother, E. H. Ross, at Fort Said, gave me an appointment as probationer in that Service, for which I abandoned the Medical Service of the British Navy—in the hope of having better opportunities for scientific and sanitary work. In the autumn of 1906, His Excellency Mansfield Pacha, then the Commandant of the Cairo City Police, suggested to me that an experimental campaign should be instituted privately in the Muski district near the police headquarters. Most of the necessary funds were provided by the police, and Mansfield Pacha used his influence to get subscriptions from the other residents whose property was to be treated. The campaign included the building of the Mixed Tribunals, the Opera House and the Esbekieh Gardens. This campaign is an interesting one, for the whole area involved was very small, about half a square mile of densely-populated buildings situated right in the heart of the city, where the houses were, if possible, more infested by
mosquitoes than elsewhere. The result was remarkable, for in three months the mosquitos had practically disappeared from the area treated, whereas all round they remained as bad as ever. Every cesspool was oiled once a week with a mixture of refined and crude petroleum in equal parts. All water vessels were overturned and dried out. In the Opera House the audience could watch the performance in comfort owing to the mosquito campaign, whereas if anyone crossed the street to one of the un-campaigned houses, he would be pestered by hundreds of insects. This campaign proved the point that mosquitos will not migrate far from their original breeding-places. We received no opposition whatever from the inhabitants, in spite of the fact that the majority of them were Europeans, and incidentally hashish and gambling dens were discovered and reported to the police.

Early in 1907 a new campaign was started in Kasr el Dibana by myself under the orders of Sir H. Finchling. This district is bordered by the Nile and contains the best residential houses in Cairo, including the British Agency. It is right to mention that this campaign was restarted largely at the instigation of Lady Cromer, who suggested that it might be instituted on scientific lines by a responsible official; not by private enterprise, like the first attempt in 1904. Sir Horace Finchling ordered the funds to be provided after a rough estimate of the cost had been prepared. The next step was to obtain permission from the residents themselves to allow us to enter their houses. It was considered preferable to obtain permission from individuals rather than from their consuls, because at that time some of the consuls in Cairo were not on very friendly terms with the Government. Letters printed in several languages were sent to the residents, and a large number were soon answered giving permission. The European residents never appeared to object when they appreciated that they would have nothing to pay—a point which was clearly stated in the printed letters. Curiously
enough, the only persons who objected were the natives who had no right to refuse. We could, of course, have entered the houses of the local subjects without their permission, but Egypt is governed by a diplomatic administration rather than by a scientific one, and it seemed more diplomatic to treat both native and European alike. The objectors were called upon and the campaign explained to them. Lady Cromer came to the rescue, and was indefatigable in calling and seeing personally many of those who refused to allow us to enter their houses, and allaying their suspicions. By the end of January the campaign was in full swing, the brigade consisting of a European foreman and two native labourers.

In about three months, when the mosquitoes ought to have been reappearing owing to the return of the hot weather, the residents noticed that their houses remained practically free, in spite of the fact that the pest was assuming its usual proportions in the other uncamphied parts of the city. One by one the objectors asked that the campaign might be instituted in their houses, for they began to realise the benefit of it. For instance, one of the gentlemen who objected to the campaign at the outset was a native prince. His palace, therefore, was not entered. After a few months his neighbours began to complain that the mosquitoes from his house annoyed them; and he, on entering their houses, remarked on the reduction of the number of gnats. Suddenly a polite letter was received asking for a visit from the brigade, and the letter was followed by a visit from the objector himself, who implored us to destroy his mosquitoes. From instances such as this we learnt that it is better to ignore objections to the visits of a brigade rather than to endeavour to persuade people. Let the campaign be continued in the houses of others; after a short time I think that it will be found that all objections will disappear.

The following October, when the mosquitoes ought to have been at their worst, Kasr el Dubarra enjoyed comparative
immunity from them, and at the Semiramis Hotel, which is in the district, visitors and tourists could sleep without mosquito curtains, the only place of this nature in Cairo where this has ever been done.

At the beginning of 1907, on the initiative of Sir H. Pinching and Major Elgood, a small campaign was also started by me in the Police School at Cairo. This school contained about five hundred students, recruits for the Police Force in Egypt, and it was established in an old palace in the Abdin quarter of the city. The palace is a very large building surrounded by a garden. It is built on the native plan in the shape of a quadrangle with a large courtyard in the centre. It was infested with mosquitoes, from which the students suffered greatly. The ceiling of the school hospital, which formed part of the building, used to be black with the gnats, a sight I have never seen before. Like many of these native palaces, there were more than seventy latrines, all of the native pattern, which communicated with large cesspools under the building. These cesspools were not ventilated, and the only access to them was through the closets themselves which led directly into them. In the garden there were the inevitable fountains, and a sort of pond which was used for irrigation purposes. Oil used to be poured down most of the latrines; others were sealed up. The pond and fountains were emptied. The number of mosquitoes was greatly reduced in a very short time, and before I left Cairo a year later, they had practically disappeared. Major Elgood, the Commandant of the school, then kindly undertook to supervise this campaign, and when, at a later date, the school was moved to new buildings at Abbasieh, a fresh campaign has been started there by him with most successful results. The year before this campaign was started, 26 to 27% of the personnel were admitted to hospital suffering from various forms of fever, including dengue and simple continued fever (probably some were cases of malaria). After the campaign had been in progress for some time, the
fever showed a decline, thus—June 1908 to June 1909, the incidence of fever fell to 7.2%. The average number of the personnel is about five hundred. In a paper describing this campaign, Major Elgood gives the following figures—Year 1907-1908, eighty-eight cases of dengue occurred. During the year 1908-1909, when the campaign was in progress, the number of cases fell to six.

In March 1907 a campaign was started at Heluan by myself under the orders of Sir H. Pinching. The initial procedure was similar to that adopted at Kasr el Dubarra. Heluan is a town built in the desert about 15 miles to the south of Cairo. It is famed as a health resort owing to its hot sulphur springs and dry, invigorating climate. There are many hotels and sanatoria, and the town itself is a growing one considerably larger than Ismailia. The reason why Sir H. Pinching ordered the campaign to be started at Heluan was because malaria existed there. Anophelines had been taken, and examination of blood-films taken at random from native children demonstrated benign parasites; an examination which had been made sometime previously by Dr Dreyer of the Public Health Department.

A new brigade was formed, and all the water collections and cesspools were treated with petroleum. Mosquitoes were found to be breeding in some pools of sulphur water, which had collected in some places owing to overflow from the sulphur wells. It seems that after this water has been allowed to stand for some time, the sulphur precipitates, and the larvae of mosquitoes (including these of Cellia pharoensts) will then thrive in it. An attempt was made to drain this surplus water, which will be an expensive undertaking. In the meantime, as much of it as possible was oiled. Heluan was famed almost as much for its mosquitoes as it

was for its sulphur baths; even in the winter months one was being bitten night and day. Nearly all the gardens have fountains, but unlike the houses in Cairo, the cesspools are usually to be found in the garden or courtyard. *Stegomyia* breed freely in the fountains, which were therefore stocked with fish. Some householders objected to oil being poured into the fountains because it is unsightly, and it was found that a common variety of Nile fish (*Tilapia nilotica*) is very hardy and will keep small collections of water free from larvae. The cesspools are constructed very deeply in Heluan, as the subsoil water, especially in the east and north of the town, can only be found at a considerable depth. There are not many water-closets, and the result is that some of the cesspools are dry except in "pockets" which have formed in the earth. To reach these "pockets" with oil, it was frequently necessary to send a man down into the cesspool itself. In this case a rule was made that a lighted candle was previously lowered to test for the presence of poisonous gases—an important precaution against accident.

The results of the campaigns in Cairo and Heluan may be summed up together, for in every case it was practically the same. The number of mosquitoes began to diminish perceptibly in about three months; and in Heluan, in six months, people were sleeping without mosquito curtains. Even those people who were inclined to doubt the possibility of ridding districts of Cairo of mosquitoes, had to admit that the destruction of the pest is not only a possible, but really an easy problem.

In September 1907 Dr Dreyer again examined blood-films from some children in Heluan, and found that very few parasites could now be demonstrated. No cases of dengue occurred there during the autumn of the same year, although an epidemic of the disease was in progress in other parts of Egypt.

Apart from the prevention of disease, however, mosquito campaigns are valuable measures to be adopted in a country like Egypt, for they bring the officials who organise them more
in touch with the inhabitants, who, consisting largely of natives, are inclined to mistrust those set above them. Mosquito brigades are constantly visiting the houses, and when the inhabitants appreciate that something is really being done for them, they take an interest in the work, and ultimately further this and other sanitary reforms. When I left Egypt in January 1905 there was no one who objected to the visits of the mosquito brigades, nor were there any complaints that any member of them had abused the privileges conferred on European subjects by the Capitulations. In fact, the Capitulations put little real difficulty in the way of sanitary reform. Europeans and their consuls are fully alive to the possibilities of scientific measures properly carried out; and if Europeans and even natives are assured that efforts to improve sanitation are made conscientiously, I believe that they will forgive, as has been proved by the mosquito campaigns, the one privilege which they prize, namely, an immunity against interference by Government officials. The difficulty caused by the domicile clause of the Capitulations, which is used as a cloak for nearly all administrative sins, vanishes in the face of a mosquito campaign. The experience gained in Cairo and Heluan proves conclusively that mosquito destruction is a desirable measure to be adopted in Egypt, and it is remarkable that this fact was not appreciated before.

Unfortunately, Sir Horace Pinching, who had been so sympathetic towards this work, retired in the autumn of 1907 from his post of Director-General of the Department. His successor immediately told me that he did not consider it necessary for me to continue the work, and he treated me in such a manner that I was obliged to resign my appointment in the Department. At the same time my brother, E. H. Ross, was also threatened in my presence with dismissal. It will therefore be understood that since these events the Government has become lethargic about anti-mosquito measures. I have heard that mosquitoes have returned in the parts campaigned
in Cairo; and at Helwan, and even Port Said, the pest is reappearing. I have seen frequent complaints in the Egyptian newspapers that the campaigns have been allowed to fail, and I fear that for the time being mosquito destruction has fallen into disrepute in Egypt.

From my experience of the Public Health Department, I think that the Government does not appear to appreciate its responsibility regarding sanitary administration. A visit to Cairo will show that nearly all improvements are made by private enterprise. When a new town is started, such as Heliopolis Oasis, it is started by a company. The most modern buildings in the city itself, erected for the public, have been built by His Highness, the Khedive, on his own private property. Yet the Government owns nearly all the vacant land round the city, and it refuses to part with it. The result is that the city is becoming overcrowded, with an enormous death-rate.

Calculated on the 1907 census, the death-rate of Cairo was, for 1906, 32'73 per 1,000; and for 1909, 44'9 per 1,000. In an article published in the British Medical Journal on 10th April 1910, which describes the state of the sanitation of Cairo, it is stated that 28'2% of the infants born in Cairo die during the first year of life; and 48'5%, or nearly half, of the children born will, if the present death-rate continues, die before they reach the age of sixteen years. When I was in Cairo, in certain districts in the Saida Zenab quarter, known as El Mardi and El Sakkia, Government properties, the death-rate reached 20%, and yet the Government will not allow the city to expand, and appears to await a rise in the value of the property before it will part with it. My personal opinion is that the fault is due to the fact that the country is governed almost by amateurs. The sanitary officers are not bound to obtain Public Health Diplomas, and it seems to me that many of the higher Government offices are placed in the hands of friends and relatives of existing officials, apparently without regard as to qualification. I have shown that the laws are difficult to enforce. There is no building
law whatever; anybody can build any hovel he pleases. Few reports are published from the Public Health Department, and officials under the present regime are not permitted to print the results of their work for the benefit of their successors.

Mosquito extermination, however, is bound to be undertaken seriously in Egypt under more competent management. For the time being, perhaps, it will remain in abeyance, but it is a measure which is so certain in its results and so far-reaching in the good which it does, that before long, I think, it will be generally demanded by the public. It is nauseating to live in Cairo in the summer and to be bitten persistently by insects which breed in excrement. Mosquito destruction is an unpleasant though a simple problem. It must be continued unremittingly, or the gnats will return; but the cost of the campaign will fall to a certain extent after the initial destruction of the pest. I hope that the work will be started throughout Cairo, for I know that the results will be greater than were ever anticipated.
By ANDREW BALFOUR, M.D., B.Sc., FR.C.P. EDIN.,
D.P.H. CAMB.
Director, Wellcome Research Laboratories, Gordon College, and
Medical Officer of Health, Khartoum

54. The Campaign at Khartoum.—In the pre-Dervish days Khartoum must have been a hot-bed of mosquito life. This is apparent from the evidence of Sir Rudolph Baron von Slatin, who states that mosquitoes were very prevalent during this period, and from that of Father Ohnvalder of the Austrian Mission, who asserts that he was sometimes driven to go and stand up to his neck in the Nile in order to avoid the attentions of the winged hordes. That malaria was also present cannot be doubted. Schweinfurth speaks of the unhealthiness of the place in a manner which leaves little doubt but that one of the chief causes of the high mortality which obtained at certain periods was malarial fever. It is believed that its evil reputation was one of the reasons which induced the Mahdi to abandon its site altogether, and, with that empirical wisdom which often characterises the native, to found Omdurman on a spot where the river banks are not bold and terraced but shelving, and consequently free from pools at low Nile. Some four years after the new city had come into being, a survey of the conditions as regards mosquito prevalence was made. This disclosed the fact that three genera, represented by three species, were constantly present, namely, in order of frequency, Culex fatigans, Stegomyia mitchelli and Pyretomia costalis. Malaria was found to exist, and it was shown that infection could be acquired locally, while numerous cases were always being brought into the town by steamers coming from the highly malarious regions to the south. It was towards the close of
1903 that anti-mosquito measures were instituted and a small mosquito brigade established. These measures have continued in force ever since, and the brigade has been constantly employed. One of the chief points elucidated by the work is the absolute necessity for its continuity. In a place like Khartoum it is essential to carry out preventive measures year in and year out, and two mottoes most suitable for those in charge might well be "Weary not in well-doing," and "Do not put overmuch trust in the native inspector."

In this brief note we are only concerned with the single species of Anopheles which constitutes itself a danger to the town, and may omit any detailed account of the work in connection with the two other species of Culicid mentioned; but it is well to point out that in practice these latter cannot be neglected. Mosquito prevention measures must be general, and it is very often the operations against Culex or Stegomyia which lead to the discovery of invasion or threatened invasion by *Pyretophorus*.

*P. costalis*, then, is the malaria carrier of the Northern Sudan, and so far as Khartoum is concerned its breeding-places were found to consist of—

1. Pools left by the falling Blue Nile. These are found for the most part in the sand-banks which appear in the river's bed, but may also occur in the sloping and terraced banks as the river falls.
2. Garden tanks.
4. Permanent garden pools.
5. Sakia pits, as used in irrigation work.
6. Irrigation channels and pools formed by leaking "gud wals," as the large and small canals are termed.

The only large area of irrigated land is at Khartoum North.
7. Wells.
8. Rain-water collections.
Household water collections, such as water stored in barrels. These are not at all common.

Water collections on steamers, provided these be exposed to the light, i.e., in boiler trays, cisterns, etc.

Chance water collections, as in old barges and leaky boats where speedy water evaporation is prevented.

One or two of these breeding-places merit a few words of explanation. The soil in some parts is what is termed "weeping." It contains a large quantity of salt. Hence if gudwals are constructed of this soil the water dissolves out the salts, and leakages soon result, pools form, and, despite the fact that the water is brackish, *P. costalis* readily lays her eggs in such collections. This mosquito is very rarely found in wells, but its larvae have once been encountered in a well 70 feet in depth. This is so peculiar that one wonders if they had not been accidentally introduced. Rain-water collections are rare in Khartoum, but occasionally the summer is comparatively wet, and then pools and puddles may persist for some time. They are not commonly utilised as breeding-places by *P. costalis*. This Anopheline is not often found breeding out on the river steamers, but has been known to do so, and may be introduced into Khartoum as *imagines* both by steamers and by native boats. Recently a species of *Nyssorhynchus* has been apparently introduced in this manner. It is worth noting that since operations were started cases of malaria locally acquired in Khartoum have never once occurred without the presence of Anophelines in or near the town being demonstrated.

The chief methods of prevention and reduction put in force may be tabulated as follows:

1. Systematic inspection.
2. Notification of cases of malaria.
3. The issue of warning notices and distribution of information.
4. Petrolage.
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5) Filling in of pools and abolition of water collections such as garden tanks, bath-waste pits, etc. Also the screening of cisterns.

6) The introduction of fish into water channels.

7) The pipeing and covering of raised water channels to prevent leakage through their banks.

8) The imposition of fines.

9) General legislation as regards borrow pits, irrigation, engineering work, and the provision and maintenance of dry zones.

All three forms of malaria used to occur in Khartoum. Benign tertian was the most common, malignant next, while quartan was rather infrequently encountered, though it has been found to be much commoner than was at first supposed. Quite a large number of cases harbouring crescents annually come into the town from the Upper Nile and the Bahr-el-Ghazal Province.

Some of these measures call for a little further notice. The inspection must be thorough and the native inspector must be controlled by trained and reliable British sanitary inspectors. The town is divided into sections, each of which is in charge of a native who has no sooner completed his round than he begins again. In this way, if he does his work properly the inspector should visit every house and every water collection in his district at least once a week. The British inspectors are responsible for the whole town, and often combine mosquito work with house-to-house inspection. Areas bordering on the river, the point of danger, are in charge of the most experienced men, and a special native inspector is detailed for steamer and boat work. Khartoum has a population of some 15,000; Khartoum North, of about 25,000; and there are in all at the present time three British sanitary inspectors and seven native inspectors. Of these one British and two native inspectors are responsible for Khartoum North, where with

5 Mosquito prevention is, of course, only a part, though an important one, of the work of these inspectors.
the exception of some pools on a sandy island there are no river pools, the banks being high and steep, and, where there are scarcely any gardens, the only dangerous area, so far as P. costalis is concerned, being a large stretch of irrigated land and certain small irrigation channels which are apt to leak and form pools. The dockyard is situated at Khartoum North, and the steamers require constant attention, but more for Culicidae and Stegomyia than for Pyrrhoporus. When necessary, extra men are employed filling in river pools; and if these happen, as at present, to exist in sand-banks opposite the so-called British Barracks, the services of the British troops tenamenting these latter are at once solicited, and never in vain.

Notification has proved of great value. It stimulates enquiry and has often led to the discovery of breeding-places when such would otherwise have been missed.

Here are types of the warning notices inserted at intervals in the local press, especially during the winter when the Nile is falling, and again during the brief rainy season in August and September.

SANITARY NOTICES

"The attention of householders and others is again called to the necessity of properly emptying and drying out tins and other vessels holding water least once a week, in order to prevent mosquito-breeding places. Persons proceeding on leave are especially requested to see that this is done before premises are left vacant. Any one found harbouring mosquito-breeding places is liable to be punished in accordance with Town Regulations, and in future stringent action will be taken to put an end to this nuisance and danger to health. It is not enough to instruct servants to carry out these measures. There must be personal supervision. Five minutes per week is no great tax on the time of any one."

"Householders are urgently requested to give immediate notice to the Sanitary Inspector at the Mudiria if they find themselves troubled by mosquitos or note their presence. Any one found harbouring larva or pupae on his premises is liable to be fined, and stringent action will be taken, as malaria-carrying species are at present endeavouring to obtain a footing in the town."
The regulations as regards steamers are of practical interest and are also given below. When carefully followed the results have been excellent.

1. Before leaving Khartoum the bilge water in the various sections should be nipped by pouring petroleum on the surface of the water and stirring well with a stick. A film will then form on the surface, which prevents access of air to the mosquito larvae and pupae, and so kills them. Eggs deposited by mosquitoes on this oil film will not develop, and many of the females themselves will be killed. Roughly, about one half-pint of oil should be devoted to each section. A little experience soon shows how much or how little oil is needed to form a proper film. In addition, the water in the trays under the boiler should be examined, and, if necessary, oiled.

A cup or wide-mouthed bottle can be used for collecting water for examination. The vessel should be quickly but gently dipped under the surface and lifted out without spilling any of the contents. For somewhat inaccessible places a tin with its bottom replaced by wire-gauze mesh and attached to a stick is useful. The larvæ are then found wriggling on the gauze. Such a collecting dish is easily made and answers well. It should be examined in a good light. It is to be remembered that any standing water collections will harbour mosquito larvae, and attention should therefore be paid to the water-closet cisterns, zeers and tanks.

2. During the voyage opportunity should be taken to re-col the bilges wherever possible. This should especially be the case before starting on the return journey. Wood holds are usually at fault. The difficulty can be got over by emptying these in rotation, so that the water in the hold can be got at and nipped once in every fortnight. Special attention should be directed to zeers when these are used for storing bottles of drink. All zeers should be emptied out at least once a week during the voyage.

3. The thing to be avoided is returning to Khartoum with mosquitos on board. If this is done, wells and water collections in the town which have been cleared at trouble and expense are liable to become reinfected. This has happened repeatedly, so that it is very important that steamers should arrive clean and free. It is well to have all bilge water emptied on arrival, and all steamers lying up should be inspected and treated in the manner described. Similar precautions are required in regards barges, sandals, launches and any vessel on which there is stagnant water.
THE CAMPAIGN AT KHARTOUM

It has been proved that mosquitoes, as a rule, will not stay for any length of time on a steamer if they are prevented from breeding out on board. Consequently, insecticidal methods are effective, as has been demonstrated in several instances; and there is no excuse, in most instances, for steamers reaching Khartoum with their bilge water, etc., full of larvae and pupae, and their cabins full of adult mosquitoes. Sometimes it has been found advisable to employ sulphur squibs when there were many adult insects in the holds.

A little space may be devoted to the introduction of fish which has been successfully employed in the irrigation channels at Khartoum North and, as will be seen, elsewhere in the Sudan.

A zealous and interested official some time ago suggested the introduction of the small "millions" fish (Girardinus poeciloto) from Barbados to cope with larvae in swamps, irrigation channels, large pools and like collections of water. The question was referred to me, and I found myself opposed to the idea, partly because I know the difficulty of transporting these fish, and the possibility that they might not take kindly to new surroundings, and partly because, like the proud Syrian of old, I was tempted to reply: "Are not Abana and Pharpar, rivers of Damascus, better than all the waters of Israel?" In other words, one was of opinion that there was no use going outside for what might very well be obtained at home. I knew that Captain Flower, Director of the Zoological Gardens at Ghizeh, employed young "Buli" (Tilapia nilotica) in the tanks of the aquaculture at Ghizerh, and found them most efficient in keeping the water free from mosquito larvae, and it was reasonable to suppose that many Nile fish were effective, especially as it is found that when fish are present in any pool left by the falling river, mosquitoes do not breed out therein.

There were two points, however, requiring attention. If any water collection is stocked with fish, these latter are apt to be speedily cleared out by natives or birds, such as kingfishers, which are very plentiful. Moreover, as is explained later, fish
which attain any size are not suitable for use on irrigated land. Hence, it was desirable to find a small and greedy fish which would offer no temptation to the native, which could be used in irrigation channels, and which, though not immune from the depredations of fish-loving birds, yet was so prolific, or could be used in such numbers, as to make these ravages of little account. The type of fish desired was that known in India as the Chilwa (Chela argentea), which is said to be more efficient than "millions," as not only does it devour the larvae but, being a surface-feeder and an eager fly-taker, it is deadly to the adult mosquito, especially to the female intent on egg-laying.

As Mr Harold King, our entomologist, was going up the White Nile in the Floating Laboratory on a voyage of discovery, I asked him to take every opportunity of studying the question. Mr King is an excellent field-naturalist, and admirably fitted to carry out such an investigation. His report, which I append, will be found of interest and value, and it would appear that in Cynolebias insignis we have obtained the fish we require. This, as Mr King remarks, remains to be proved, but the following letter, kindly sent me by the Acting Manager, Sudan Plantations Syndicate, in whose irrigation channels the fish are being tested, is at least promising :-

"DEAR SIR,—In reply to your favour of the 19th inst., I have examined the small canal into which the fish have been introduced.

"The canal is about thirty metres long and about half a metre deep, and the opening to the larger canal is closed with gauze-wire netting to keep other fish out. Although the still water is now lying twenty-five days there are no signs of mosquito larvae. The fish are alive and seem to feed on flies on the surface of the water, and are most active in the early morning.—Yours faithfully, ALEX. MACINTYRE."

Like Mr King, I have fed Ophiobolechus obscurus (vide infra) on the larvae of Culex pipiens, and noted how the
THE CAMPAIGN AT KHARTOUM

latter were devoured before ever they reached the bottom of the jar.

The following is Mr King's report:

"While on the White Nile, between the dates of 17th April and 19th July, I carried out some investigations with Nile fish with a view to ascertaining what species, if any, were likely to be of value in controlling mosquitoes by feeding on their larvae. In most of the swamps, where mosquito larvae abounded, shoals of small fish of various species occurred, but from the fact that the two thrived together it was evident that the fish were not likely to be of very much use. Numbers of those fish were captured, placed in jars and offered mosquito larvae, but with one exception they refused them until they had passed one or more days without food. The exception was a fish found in a khor between Gebel Ahmed Aga and the river. In this khor very few mosquito larvae could be found—a search of nearly two hours resulted in less than a dozen specimens being taken—but there were present numbers of the young fry which has been identified by Mr G. Boulenger of the British Museum as Ophiocephalus obscurus.

"This fish feeds greedily on mosquito larvae, thrives well in captivity and in stagnant water, and appears to be an ideal fish for the purpose for which it is wanted, except in one respect, viz., size. When full grown it attains a length of 35 centimetres. As fry, inhabiting shallow waters such as are found in swamps and river-spills, this fish would no doubt prove of value, for it is in just such places that mosquitoes breed. On the other hand, though the fish would flourish in large irrigation canals, and the fry could reach the smaller gutters on irrigated land, the latter are frequently so constructed that the young fish on increasing in size could not regain the parent canals and would perish. Hence this species of fish is not likely to be an economical means of dealing with mosquito larvae in such situations.

"Some thirty specimens of O. obscurus are still living in a jar in the Laboratories.

"During May, I met Mr Bltter, superintendent of game preservation, who told me of a small fish—Cynolebias simplex—which lives in Khor Arbat, about twenty-two miles from Port Sudan. He very kindly furnished me with some notes on its habits, and recommended that it should be given a trial as it appeared to him to be likely to give good results. He further said that, while no mosquitoes are noticeable in the vicinity of
that khor, they are plentiful near other similar khors where
*C. dispar* does not exist.

Accordingly, on 6th September, I left for Khor Arbat and,
having spent three days there, returned to Khartoum on 12th
September. There were myriads of the fish in the khor, but
at first I had considerable difficulty in persuading them to live
in captivity. Eventually, I found that while, if placed in jars
nearly full of water, most of them died within twelve hours,
et if given only about two inches of water over a layer of sand
they could be transported fairly easily. One hundred and one
living specimens reached Khartoum, and were there offered
mosquito larvae, which they took readily. This, however, is
not conclusive proof that *C. dispar* feeds on mosquito larvae in
its wild state, as the specimens had been unfed for two days
when the larvae were given them, none being obtainable at
Khor Arbat.

As these fish did not thrive in jars I wrote to Mr Macintyre,
Acting Manager of the estate at Zeidah, belonging to the
Sudan Plantations Syndicate Ltd., asking him if he would
allow them to be placed in a gudwal on the Company's estate
for purposes of experiment. This he readily agreed to; so that
on 19th September I took those that were still alive—about
seventy in number—to Zeidah, and the following morning
liberated them in a short length of gudwal which Mr Macintyre
very kindly had filled with water. This gudwal is not used at
present, for agricultural purposes, and the pipe connecting it
with the canal has been netted to prevent other fish gaining
access. This was done in order that the *C. dispar* might be
given every chance of establishing themselves before being
subjected to the possible ravages of other and larger fish.

The specimens liberated at Zeidah were all immature, as it
was found that partially-grown fish withstood captivity better
than did adults.

When full grown, *C. dispar* attains a length of 8 centimetres,
and in all stages appears to prefer shallow water.

Should the gudwal in which these fish were liberated remain
free from mosquito larvae during the coming year, while similar
gudwals in the immediate vicinity serve as breeding-places for
these pests, I think sufficient proof of their value will have been
obtained to justify an effort being made on a larger scale to
establish *C. dispar* throughout all the gudwals on the Sudan
Plantations Syndicate Ltd.'s estate, and on other similar farms
where great difficulty is experienced in controlling mosquitoes.”

As regards legislation the following irrigation rules, imposed
on all who take up land with a view to cultivation on a large scale, may be quoted with advantage. They are of very great importance both from the sanitary and the economic standpoint.

1. Irrigation channels should be constructed on a higher level than the surrounding land, so that when the flow of water in them ceases they may drain dry.

2. They should be constructed of such material and in such a manner as to prevent leakage.

3. Their banks and beds should be kept in good repair, and the beds even, to prevent the formation of pools.

4. "Dead ends" of irrigation channels should be reduced to the smallest size compatible with efficiency, so that water will not stagnate in them.

5. Vegetation should be periodically cleared out of the channels.

6. Sluices should be constructed so that there is no leakage to form stagnant pools.

7. Where possible, fish should be introduced, and kept in the main channels to destroy the larvae.

8. Lands where water is apt to stand should have proper surface drainage.

9. Crops, such as sugar-cane, rice and others which require to stand in water, should not be grown within half a mile of any town or village.

10. If an engine or pump should happen to break down, particular care should be taken to deal with stagnant pools, and petroleum should be used when necessary.

11. Cases of malarial fever, and any prevalence of mosquitoes, should be notified to the governor of the provinces by the manager of the concession.

The above is a brief outline of the measures adopted and the work accomplished. What has been the result? It is difficult to give comparative statistics, as we do not know how much malaria used to be locally acquired in Khartoum; but we do know that P. ovale is used to be fairly common, especially at certain times of the year; while now it is wholly absent during many months, and if it does invade the town its breeding operations are usually quickly checked, it does not multiply, and soon disappears. As a direct consequence locally acquired malaria has become very rare. One cannot
wholly trust the notifications, but they afford considerable
indication of how matters stand, and, so far as Egyptian and
British troops are concerned, are trustworthy. Here, then,
are the locally-acquired cases for the past few years.

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(16th January 1908)

It is very rare for a British official or European resident
to acquire malaria in Khartoum itself, with I should say that
owing to increased trade and communication more cases are
now imported than was previously the case. There can be
no doubt that if operations were suspended Khartoum would
speedily regain, if not its old evil reputation, at least a certain
measure of the same. At the time of writing there is a good
deal of malaria in the neighborhood of the town, i.e., in villages
a couple of miles to the north, in one part of Qarun, and
and at various places along the White Nile. Arab physicians
now, as previously, are endeavouring to obtain a footing in
the town, and have been blown into it by the wind or brought
into it by boats. As a result, we have had a few cases, mostly
in British soldiers who were wont to wander out to the east
of their quarters towards a part of the river where there are
extensive sand-banks and many pools, some 23 miles from
the center of the city. Had operations not been in force I am
very certain that this year would have witnessed an epidemic;
for conditions seem specially favourable to the propagation
of *P. falciparum* at present, and, as stated, there is much malaria

...
in the neighbourhood. A measure which has had good effects is to put any dangerous area out of bounds for British troops.

One may conclude by stating that Khartoum is a favourable place for carrying Professor Ross's methods into effect; and that they have met with marked success, and doubtless will continue to do so, provided the work is carried out continually, thoroughly, consistently and with intelligence, so that the influence of immigration is borne in mind and that legislation provides for the control of irrigation and the regulation of irrigated areas.
Malaria in South Africa.—British South Africa as a whole does not suffer much from malaria. Along the east coast, in Portuguese East Africa, Swaziland and Zululand, the disease is common enough and occasional outbreaks occur in a few parts of the Cape Colony and Natal. A recent outbreak in Durban assumed serious proportions.

In the Transvaal the disease is endemic in the Low Veldt, in the east and north of the country; and the type is severe, bilious, remittent and haemoglobinuric forms being common. Owing to paucity of population in these districts the disease attracted little attention until the building of the Pretoria-Delagoa Bay railway line, when the heavy death-rate forced the disease upon the public notice. No effort was, however, made to combat the disease until I was appointed District Surgeon here, and commenced to make representations to Government on the subject in 1903. The work was started in 1904, and immediately its results were obvious in a greatly reduced sick-rate. The Railways then requested me to make a fever survey of the main line and the Barberton branch, and to make recommendations for each station. I obtained the assistance of the Government Entomologist, the late Mr. C. B. Simpson, for this survey, and our recommendations being promptly carried out, resulted in a considerable reduction of fever along the line.
Every station and ganger's cottage from Komatipoort to Waterval Onder was dealt with, local measures for mosquito reduction carried out, and all railway quarters in the Low Veldt made mosquito-proof. We were compelled to rely chiefly on the latter method of fever prevention, owing to the small number of persons concerned, and the great amount of work necessary to deal with the breeding-places along the Crocodile River, which runs parallel to the line. All small breeding-places in the immediate neighbourhood of the stations were dealt with.

To the Central South African Railway belongs the credit of first efforts to combat malaria in the Transvaal, and since 1905 the apathy of the public and the authorities has been gradually overcome. The results obtained by the Central South African Railway proved a powerful argument, and now the value of anti-malarial measures is fully recognized by private residents and the different Government departments who have officials in this part of the Transvaal. Practically every private resident in this town has now a mosquito-proof bedroom; and in the country many farmers have also adopted this precaution. Mosquito-proof quarters are being provided for all police posts in the Low Veldt, and also for the officials of the Government Game Reserve, which lies north of the Crocodile River. The Colonial Secretary's Department have now arranged to issue free quinine in all fever districts in the Transvaal to all indigent whites and all natives; the Barberton municipality have lately taken up the subject; and a League has been founded for the purpose of carrying on the anti-malarial campaign throughout the district.

Anti-malaria methods employed at Komatipoort. — Anti-malarial work was commenced at Komatipoort in 1904, the cost being borne by the Central South African Railways. The town is rather unfortunately situated, in the angle between the Crocodile and the Komati Rivers. Along both rivers are
A SHOOTING ENCAMPMENT ON THE LIPUSER:

Employing fishing as a valid pastime.

A TENT IN THE FEDERATION TERRITORY:

A tent used by the British Army in the Transvaal, formerly occupied by the Zulus, by Major Hamilton.
A military block house, bought in 1858 after the war, covered by a thatched roof and windows, was very comfortable and well-furnished.
A small house designed for farm workers, built by the C.S.I. at the cattle ranch, Selous Mission, Tanzania.
5. Joint offices of the North-Western Native Labour Association, but the office itself is situated in the district of East Africa.

Native Mansion that passed through the sliding door in the meeting. He was in the photo film, not in the building.
backwaters, pools and inlets, with dense vegetation in parts, and below the junction for some acres of broken, rocky ground holding innumerable small pools. The worst breeding-place of Anophelines, however, was a swamp running parallel to the railway and opposite the station. The swamp was fed by a small seeping and surface drainage, and by the waste water from the pump and engine sheds. It consisted of about two acres of ground only, but the whole of it was a network of small pools amongst thick reeds and rush vegetation. Anopheles mosquitoes were breeding here in great abundance, and it was decided to obliterate this swamp entirely. A brick and cement drain was cut through the centre to carry off the water supply which maintained it. The ground was cleared, all pools filled in, and the surface evenly graded from each side down to the drain to carry off the rainfall. The reclaimed ground was planted with banana trees and eucalyptus, and absorption of water by these has sufficed to keep the area perfectly dry, and the former swamp is now, on a small scale, a town plantation. Efficient treatment of the main rivers was impossible on the score of expense; but the portions of them within half a mile of the town were dealt with by filling in some pools by rubble and cement, and a mosquito gang having been organised, larger pools were treated with paraffin.

These methods proved in practice to be most satisfactory. Only partial reduction of mosquitoes had been attempted, but it was subsequently found most difficult to discover any specimens of Anophelines within the town area. At the same time all railway servants' quarters were made mosquito-proof, and the reduction of fever cases was marked and immediate.

The following table is taken from a report on the subject made to the General Manager of the Central South African Railway in December 1905.
Cases of malarial fever among Central South African Railway employees—Komatipoort—Kaapmuiden section—

<table>
<thead>
<tr>
<th>Month</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>212</td>
<td>396</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>238</td>
<td>401</td>
<td>42</td>
</tr>
<tr>
<td>March</td>
<td>288</td>
<td>340</td>
<td>39</td>
</tr>
<tr>
<td>April</td>
<td>294</td>
<td>304</td>
<td>33</td>
</tr>
<tr>
<td>May</td>
<td>277</td>
<td>198</td>
<td>30</td>
</tr>
<tr>
<td>June</td>
<td>209</td>
<td>230</td>
<td>34</td>
</tr>
<tr>
<td>July</td>
<td>172</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>August</td>
<td>255</td>
<td>62</td>
<td>2</td>
</tr>
<tr>
<td>September</td>
<td>30</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>October</td>
<td>191</td>
<td>411</td>
<td>19</td>
</tr>
<tr>
<td>November</td>
<td>734</td>
<td>90</td>
<td>7</td>
</tr>
<tr>
<td>December</td>
<td>317</td>
<td>57</td>
<td>8</td>
</tr>
</tbody>
</table>

The above figures are gross details, and represent each case counted for every day of illness, that is, they are "days lost" by the whole of the railway staff. The actual daily average of the number of sick during March 1905 is 218, against a similar average for the same month in 1904 of 136.

The work of proofing the quarters was begun in June 1904.

Portuguese East Africa.—With the exception of the town and district of Lourenço Marques nothing has been undertaken, but the Portuguese authorities have taken up the subject with great energy in the town of Lourenço Marques, with the result that the town, once extremely unhealthy, is now comparatively free of the disease.

The Municipal Health Officer, Dr. Amaral Leal, has controlled the work, while the Government Entomologist, Mr. C. W. Howard, has carried out an investigation of the local mosquito problem. Their methods have been the draining of a swamp, which was the chief breeding-ground; organisation of anti-malarial sanitary measures; appointment of special sanitary inspectors, with power to inspect all houses and compounds, and to enforce the carrying out of their instructions; the treatment of all breeding-places; and the netting of Government offices and quarters.

1 In speaking of anti-malarial measures in Lourenço Marques, I should like to put on record the good service rendered on this subject by A. W. Bowly, Esq., M.C.
All offices and quarters on the Portuguese railway between Komatipoort and Lourenço Marques are now mosquito-proof.

The following is a list of mosquitos which are prevalent in this Colony. The larger number of them were collected at Nelspruit in the season of 1904-1905.

<table>
<thead>
<tr>
<th>Anopheles</th>
<th>Fyziophora</th>
<th>Mansonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>aponorhemus</td>
<td>manubria</td>
<td>manubria</td>
</tr>
<tr>
<td>bostocki</td>
<td>simsoni</td>
<td>simpsoni</td>
</tr>
<tr>
<td>bostocki</td>
<td>jenini</td>
<td>tridalis</td>
</tr>
<tr>
<td>jenini</td>
<td>philadephia</td>
<td>jenini</td>
</tr>
<tr>
<td>philadephia</td>
<td>jenini</td>
<td>philadephia</td>
</tr>
<tr>
<td>jenini</td>
<td>philadephia</td>
<td>jenini</td>
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<td>philadephia</td>
<td>jenini</td>
<td>philadephia</td>
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<tr>
<td>jenini</td>
<td>philadephia</td>
<td>jenini</td>
</tr>
<tr>
<td>philadephia</td>
<td>jenini</td>
<td>philadephia</td>
</tr>
</tbody>
</table>

In addition to these there are a dozen other species of rare genera, which as far as we know, are of but little or no economic importance. In the early part of the season the commonest Anopheline mosquito at Nelspruit is $P$. cinerrus, and later in the season $M$. manubria and $M$. manubria. The former is much more abundant than the latter, especially in March and April. It seems that the abundance of these last two mosquitos is quite parallel with the abundance of fever. While all of these may carry fever, the two latter are, in our opinion, the most important agents of transmission. Stegomyia fasciata is by far the most abundant mosquito in the Low Veldt. It is followed by $C$. simpsoni, $C$. jenini, and $C$. simpsoni in order of abundance. — From Bostock and Simpson [1905].

I have obtained from Mr. Howard, the Chief of the Entomological Section of the Agricultural Department, Lourenço Marques, the attached report on the Anopheles for the Province of Mozambique.
Distribution of Anophelines in Mozambique

In my collections in Lourenço Marques District, Gasaland, and about the Zambesi, I have taken several Anophelines. The commonest is *Pyretophorus costalis*. It seems to be distributed all along the coast, and is without doubt the principal carrier of malaria. I have always found it wherever I found people suffering from malaria. It is very abundant in the flats about Lourenço Marques, breeding even in the brackish marshes along the shores of the bay. Careful notes were made of this mosquito last season, and it was found that its increase and decrease almost exactly coincided with the rise and fall of malaria cases in town. They seem to hibernate over the dry season, in such places as grass huts and stables, although, if favourable places exist, they may breed throughout the year in sheltered localities. This, however, seems to be the exception. The same mosquito is also very abundant along the Zambesi and about Quelimane. Another Anopheline fairly common on the coast is *Nyssorhynchus paramarccius*. I have taken this on the Limpopo and Maputo rivers, but not about Lourenço Marques. It frequents houses in company with *P. costalis*, but not in such large numbers. *Nyssorhynchus pretoriensis* also occurs along the coast. My specimens seem to have been taken from Lourenço Marques District.

Another Anopheline fairly common on the coast is *Myzomyia mazzonii*. I have taken this on the Limpopo and Maputo rivers, but not about Lourenço Marques. It frequents houses in company with *P. costalis*, but not in such large numbers.

Of mosquitos other than Anophelines our commonest species along the coast are:

- *Stegomyia caffer* Meig., our commonest mosquitnext to *C. fatigalis*.
- *Scutomyia sugens* Wied.
- *Stegomyia simpsoni* Theob.
- *Culex luteolatralis* Theob.
- *Culex univittatus* Theob.
- *Gazania durbanensis* Theob.
- *Culex transvaalensis* Theob.
- *Tatsiorhyncllus auritus* Theob.
- *Mansonia uniformis* Theob.
- *Culex theileri* Theob.
- *Culex univittatus* Theob.
- *Graphomyia dawsoni* Theob.
- *Culex transvaalensis* Theob.
- *Nyssorhynchus pretoriensis* Theob.
By P. Murison, M.D., B.Sc., D.P.H.

Medical Officer of Health, Durban

55. Epidemic of Malaria in Durban, 1905-1907. — Malaria broke out in Durban during January 1905, and the number of cases rapidly increased until the cooler autumn weather set in. The following table shows the monthly notifications:

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>65</td>
<td>81</td>
<td>112</td>
<td>1,084</td>
<td>1,877</td>
<td>497</td>
<td>135</td>
</tr>
</tbody>
</table>

Some parts of Zululand are so unhealthy from the presence of malaria that they are uninhabitable.

In Durban, malaria has been a compulsorily notifiable infectious disease since 1902, and as a result an average of seventy cases were notified per annum, as existing in the borough. All these cases were found on enquiry to have contracted the disease elsewhere, and had come to Durban to recuperate.

No definite information, either from professional or lay persons, can be obtained to show that malaria had ever existed as a local infection within the borough of Durban previous to 1905. Within a fortnight of the 1905 outbreak every medical man in Durban had recognised many cases.

The borough of Durban consists somewhat roughly of a triangle, one side being bounded by the Indian Ocean, another by the waters of Durban Bay, and the base is formed by a range of low hills, in extent about 6 miles, which stretches from one end of the borough to the other. From the base of these hills to the water's edge there is a plain, being about
miles in greatest width, and probably averaging about 1
foot above high-water mark. All classes of houses are to be
found on this plain.

Chiefly along the base of these hills, this flat area is at
its lowest level, and contains many swampy areas, some of
quite small size, others extending to scores of acres.

The slope of the hills (Berea) extends to, roughly, about 1
mile from the plain to their summit, and on this gradual rising
ground have been erected dwellings of all classes.

The notifications received during the first few months
distinctly localised malaria into many areas, and these were
found to be always in close proximity to swampy or water-
logged lands.

When malaria broke out, I decided to rigidly follow the
teachings of Professor Ronald Ross, and this has been adhered
to throughout.

It was recognised from the beginning that in order to cope
with the disease both temporary and permanent measures were
necessary.

The permanent improvements were to consist of such work as
(1) The drainage of surface and water-logged and swampy
areas. The cutting of new watercourses and the extension
of old ones. (2) The filling in of swampy areas, pools, etc.,
and the levelling and grading of land to enable storm water
to flow towards some drain or watercourse. Such measures
naturally removed for all time the pools and swamps necessary
for the larvae stage of mosquito development. Since 1905
the borough has expended on this class of work approximately
£80,000.

The temporary measures consisted of the formation of a
mosquito brigade, whose work was to consist of dealing
immediately with all pools or areas of swampy lands which
were the habitat of mosquito larvae by means of larvicides
such as paraffin and disinfectants.

We discovered that the crudest and cheapest disinfectants
MEASURES ADOPTED

were the best for larval destruction, and we used disinfectants where pools were shallow, or where reeds existed in considerable numbers. We found it not only cheaper but more efficient to use disinfectant under such circumstances. One part of disinfectant to five thousand parts of estimated water in the pool was found to be effectual. Paraffin was used where pools were deep, and where an unbroken film could be formed.

Many substances were tried as larvicides, and some mechanical ingenuity was shown by those in charge of the work in endeavoring to improve the process of application of the larvicides.

As permanent improvements are carried out, the area of temporary measures was naturally reduced, and it may be stated that the only part of the borough of Durban requiring any temporary measures now is practically confined to that part known as the Eastern Vlei.

It was also recognised that the education of the inhabitants of the borough regarding the natural history of malaria was a necessary auxiliary aid in the work of prevention. We believed that a much more whole-hearted assistance would be more readily obtained if some facts regarding the disease were freely spread about so that the rationale of the work and the orders required to be carried out by householders were more clearly understood and appreciated. Hand-bills dealing with malaria prevention were left at all houses in which cases of malaria had been notified to exist, and in some areas these hand-bills were left at every house. Lectures and magic lantern demonstrations were given by me to societies, institutions, schools, etc., and I feel sure these lectures and demonstrations were a potent agent for good in our campaign.

The mosquito brigade consisted of two Europeans and about fifty Indians. Every swampy pond where larvae could breed out being treated every ten days or thereby, so as to render their development impossible.

Present position.—In 1907 the number of freshly-infected
cases were very few in number. From a circular issued to all the medical practitioners of Durban (for we had stopped compulsory notification of the disease owing to the excessive cost in 1906), the total number of cases would probably be less than a hundred. At the same time, immediately outside the borough, every household, European and coloured, was down with the disease, and the deaths amongst Indians in particular were enormous. This, in my opinion, was a brilliant object lesson as to the efficiency of the preventive measures employed within the borough. Durban can be invaded from the neighbouring country from both ends, the swampy lands here being continuous. On the reverse slope from Durban of the Berea hills the descent to the Umgeni Valley is fairly steep. This valley was saturated with malaria in 1907, but no invasion of the borough took place from this direction. The hill (520 feet) seems to act as an effective barrier. At each end of the ridge, however, where invasion did occur, an area or zone was formed, in which permanent and temporary measures were carried out as efficiently and quickly as possible. Fresh cases which occurred in the borough in that year were almost wholly confined to these areas. Government recognised the necessity for dealing with the excessive sickness and mortality in the area lying in contiguity to our borough, and started an anti-malarial movement towards the end of the season, but too late to be of any practical benefit for that year. In Durban during 1908 permanent improvements were still carried out and temporary measures maintained. No cases occurred within the borough. Outside the borough, where the disease had been rampant the previous year, and where no preventive measures of any kind were being taken, no fresh cases of malaria occurred. The disease seemed to have suddenly left Durban County.

The measures which have been carried out in Durban in order to exterminate malaria have added very much to the comfort of life, as well as to the salubrity of the town. Water
RESULTS

tanks and cisterns which were an adjunct of every house, although rendered quite unnecessary owing to the bountiful supply of water introduced into Durban, were still retained in position full of water, probably more through apathy than anything else. These were all ordered to be removed by the Sanitary Department. These tanks did not form breeding-places for Anopheles, but Culicidae developed in them in great numbers. With the vigilance which is still being maintained, Durban may be said to be at present practically free from mosquitoes of any kind. In fact, the presence of a few mosquitoes in a house is at once communicated to the Sanitary Department in order that the nuisance may be abated. Contrasted with the existing state of matters five years ago, I can only describe it as marvellous, and no people ought to be more grateful to Professor Ross of Liverpool than the inhabitants of Durban, both for the practical benefits resulting from his brilliant researches into the etiology of malaria, and for the effective preventive measures he so simply enunciated, and which have been demonstrated and proved in this borough.
The Prevention of Malaria in the Federated Malay States.—The contribution to this book sent by Dr. Watson contains a full and vivid description of his enthusiastic, long and successful campaign, carried out during the last nine years. Unfortunately, it is too long for insertion here; but owing to the interest of Sir Frank Swettenham, G.C.M.G., and a number of Rubber Companies, it will shortly be published as a separate book. I will here attempt to give only a brief abstract.

The campaign was conducted chiefly in the State of Selangor. The climate is warm and humid; the mean rainfall is 804 inches, and the country was originally covered with thick jungle, and belonged to a number of independent states. Owing, however, to the efforts of Sir Frank Swettenham, these states were amalgamated into a Federation, since when there has been much progress in the country. By reason of its products and its good Government, it is now a comparatively wealthy and prosperous one. The history of malaria prevention in it dates from 1901, and is concerned in (a) with prevention in the towns, and (b) with prevention in the district.

(1) Towns.—The two principal towns are Klang and Port Swettenham. In 1901, Klang, situated on the river of that name, contained 3,375 inhabitants, occupying 203 houses. The area of the town was about 490 acres, of which 22 acres were swamps, 25 acre single jungle, and 50 acres dense secondary growth, 30 to 40 feet high. Owing to the humidity mosquito...
bred in vast numbers all the year round. During that year the author says that the outbreak of malaria reached terrible proportions. Nearly every one was attacked, and many died. The whole population was demoralised, and when, in November, the death-rate rose to the equivalent of an annual death-rate of 300 per mille, the Chinese suspended business. In the meantime, however, Watson resolved to make a determined stand against the disease, and after consideration decided to adopt my proposals for mosquito reduction. In this he was warmly supported by Dr E. A. O. Travers, State Surgeon, by the Government, the Sanitary Board, and the people. The requisite money was voted; the marshes were rapidly drained, chiefly by counter drains which cut off the inflow. The author says, "I confess that I by no means expected the success which as a fact followed the works. I had the feeling that perhaps a 20 or 30% reduction might be obtained in the hospital returns . . . indeed I was prepared for a total failure of the works . . . I record these feelings that they may encourage others who may be disinclined by the apparent magnitude of the task from attempting to combat this disease." The success was, however, complete and lasting.

Port Swettenham is situated on the river five miles from Klang. It was founded in 1895 in order to provide a port for ocean-going steamers. The country was covered with lying mangrove swamp frequently flooded by the sea. There were few inhabitants and few cases of malaria, but Watson observed that new arrivals quickly became affected. The place was practically a mangrove swamp in which about 15 acres had been cleared. On the 15th September 1901, the port was formally opened and the Government population and coolies connected with the shipping were transferred to it. Immediately afterwards "malaria assumed an epidemic character. In less than a month the 180 loading coolies were so decimated by disease that the remainder refused to live any longer at the port and returned to Klang." Freshly-imported coolies deserted.
Out of 176 Government servants, 118 were attacked between the 10th September and 31st December. Ships came in and could not discharge their cargoes. The outbreak was so bad that the High Commissioner ordered the closure of the port until it could be made more sanitary. In the meantime Watson had recommended measures similar to those taken at Klang, and a special commission appointed by Government adopted them. "Within six weeks the work of the port was proceeded with without great difficulty. An area of about 100 acres was banded and drained and freed from jungle."

The results were immediate and decisive. The author had kept careful hospital statistics, including returns of all cases in individual houses, from facts known to him in his capacity as District Surgeon. The figures are given in a series of papers by him and Dr Travers (Journal of Tropical Medicine, 10th September, 18th November, 1st December 1903, 1st April 1905, 2nd July 1906). I attach the following abstract from my paper [1907].

1. Cases of Malaria admitted to Klang Hospital from the Two Towns compared with those admitted from District

<table>
<thead>
<tr>
<th>Years</th>
<th>1902</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
<th>1906</th>
<th>1907</th>
</tr>
</thead>
<tbody>
<tr>
<td>Town</td>
<td>610</td>
<td>199</td>
<td>69</td>
<td>27</td>
<td>53</td>
<td>135</td>
</tr>
<tr>
<td>District</td>
<td>107</td>
<td>286</td>
<td>130</td>
<td>189</td>
<td>335</td>
<td>335</td>
</tr>
</tbody>
</table>

2. Deaths in Klang and Port Swettenham

<table>
<thead>
<tr>
<th>Years</th>
<th>1900</th>
<th>1901</th>
<th>1902</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>275</td>
<td>397</td>
<td>312</td>
<td>45</td>
<td>46</td>
<td>48</td>
</tr>
<tr>
<td>Other</td>
<td>215</td>
<td>232</td>
<td>212</td>
<td>26</td>
<td>34</td>
<td>24</td>
</tr>
</tbody>
</table>

3. Deaths registered in District, excluding Towns

<table>
<thead>
<tr>
<th>Years</th>
<th>1900</th>
<th>1901</th>
<th>1902</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>42</td>
<td>143</td>
<td>112</td>
<td>178</td>
<td>189</td>
<td>271</td>
</tr>
<tr>
<td>Other</td>
<td>132</td>
<td>140</td>
<td>176</td>
<td>192</td>
<td>204</td>
<td>271</td>
</tr>
</tbody>
</table>

4. Injected Children in Towns and District

<table>
<thead>
<tr>
<th>November and December 1904</th>
<th>Klang</th>
<th>Port Swettenham</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children examined</td>
<td>112</td>
<td>112</td>
<td>112</td>
</tr>
<tr>
<td>Children injected</td>
<td>77</td>
<td>77</td>
<td>77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>November and December 1905</th>
<th>Klang</th>
<th>Port Swettenham</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children examined</td>
<td>110</td>
<td>76</td>
<td>247</td>
</tr>
<tr>
<td>Children injected</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
5. Sick Certificates and Sick Leave Granted in Government Employees
(Numbering 126 in 1901 and 281 in 1904)

<table>
<thead>
<tr>
<th>Years</th>
<th>1901</th>
<th>1902</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dates of Issue</td>
<td>279</td>
<td>50</td>
<td>73</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Dates of Leave</td>
<td>1,026</td>
<td>198</td>
<td>73</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Since 1905 the figures have not been accurately kept, but children examined at Klang show evidences of malaria as follows:

- 1906: out of 142 children, 1 infected
- 1907: 71 / 3
- 1908: 655 / 13
- 1909: 453 / 17

These are extraordinarily small percentages, considering that the district surrounding Klang was not fully treated. Meanwhile, the population of Klang had risen to an estimated total of 5,745. The results at Port Swettenham were not so permanent. The population spread into an undrained area, with the result that there was an outbreak in 1906. The cause of this was rapidly identified and removed by drainage.

The cost at Klang for the five years 1901 to 1905 amounts to $35,818 (the Malay dollar appears to equal 2s. 4d. British money). Watson says that "much money was spent in filling which could have been avoided had the town not been burdened by the legacy of its old brick drains," and there was other considerable waste. He adds that the drainage should have cost about £2 per acre, or about £800 instead of £3,000.

Thousands of acres in the neighbourhood have been cleared of malaria at this cost, and I can see no reason why Klang could not have been similarly dealt with at a similar cost," but of course many mistakes are made in first attempts. At Port Swettenham the cost amounted to $52,364. In addition to this capital expenditure there was an annual one of £270 for maintenance at Klang, and of £140 at Port Swettenham. In the former 332 acres (134 hectares), and in the latter 110
acres (45 hectares) have been dealt with. The total cost was about £1.72 per head of population for the whole five years together. The author says that in Klang "not one single grain of quinine was given to any of the population, except to those who were actual patients from malaria, in hospital or in my official or private practice." It should be observed that all this work was done before the species of carrier had been exactly identified.

(2) District.—The local Anophelines were identified by Dr. G. F. Leicester in his Culicidae of Malaya in 1904. There are nine species, of which, according to Watson, two are certainly carriers. One of these, Mr. Newsheet tells me, is certainly *M. anopheloides andrewsi*, though the genus is not quite certain, and the other is *M. williamsoni*. The former breeds all over the country, and the latter only in the hilly tracts in quickly running streams. The former can be entirely removed by ordinary open drainage channels; the latter require subsoil pipe drainage, as it will breed with facility in the open channels.

Watson's account of the extensive malaria campaign in the district is a fascinating one, but as it is concerned with numbers of scattered rubber plantations, each of which has to be dealt with separately, the history is much too detailed to be given here, though that history is an example of what can be done in rural areas under the worst conditions by all the measures, especially by drainage. I therefore content myself with giving his conclusions and some of his remarks. The former are as follows:

"(1) That both flat and hilly land in Malaya is, before opening, very malarious, and that blackwater fever has been found in both.

"(2) That hundreds of square miles of the flat land in Malaya have been freed from malaria simply by draining, and by filling the jungle.

"(3) That the cost of these rural anti-malaria measures in
8laya (where labour is dear) is about £3 an acre, being £2 to rain and £1 to fell the heavy virgin jungle. This expenditure at the same time is the first step in agriculture, and under it the land has acquired a considerable increased value.

(4) That this freedom from malaria coincides with the disappearance of an Anopheline (M. willmottia) which breeds in undrained jungle, and does not breed in open earth drains kept clear from weeds, and flowing.

(5) That certain hilly land intersected by ravines, both open and drained, is as malarious as when first opened.

(6) That the continuance of malaria here is due to N. willmottia, which breeds in ravine streams, which cannot be drained from them despite the utmost care of keeping these streams free from weeds, and which cannot be completely washed out of the ravines even by the heaviest tropical showers.

(7) That quinine given regularly greatly reduces the sickness and death-rate of those exposed to malaria.

(8) That doses of less than six grains daily are of little value if the malaria be intense—say where the spleen rate is 75% or more.

(9) That when given in 10-grain doses on six days out of seven, or in 20-grain doses when a coolie has fever, or is in such bad health that he does not feel inclined to work, between 20 and 30% of those taking the drug will still be found with parasites in their peripheral blood.

(10) That the use of quinine can therefore never result in the abolition of malaria, or even make any material reduction in the liability to infection in a malarious locality.

(11) That mosquito-proof houses have a value; but the attempt to discover a satisfactory mosquito-proof coolie house ended as an inconclusive experiment.

(12) That not only for urban, but for rural districts, anti-malaria sanitation should be based on mosquito reduction, if this be a physical possibility.

1 Intensely malarious.—R. Ross.
The author has many additional remarks to make, of which I here note the following:

1. There was conclusive evidence that the construction of roads increases the malaria in Malaya by obstructing drainage.

2. In the flat land removal of jungle within a radius of about half a mile from plantations suffices to remove malaria, as proved by many experiences over a distance of about 50 miles, but this does not suffice in the hilly land, where malaria is carried by _H. willmanni_.

3. As shown by examination of large numbers of children, proximity to jungle greatly increases the malaria rate.

4. He says, "We never seem to hear that a place always remains unhealthy, and never improves as time goes on. This is because, after a time, the population of an unhealthy place consists almost entirely of those who have acquired a certain amount of immunity. New people have practically ceased to come to it, and so the health seems to improve. But it only wants new arrivals to come in numbers to start a severe epidemic of malaria."

5. The introduction of a large number of Tamil coolies has greatly increased the malaria rate in certain plantations. This is due to the principles laid down in section 30 (17 and 18).

6. Regarding quinine prevention, he makes the following further remarks. On one estate fifty-six coolies were found to have parasites, though they were getting 6 to 8 grains of quinine, with double doses when they were ill. Of these 75% were apparently in the most perfect health, while 87% were in good health and fit for work. The author says that this "clearly demonstrated that, while keeping the malaria in check, so that the coolies can carry on their work, three years' administration of the drug had entirely failed to eradicate the disease. That the estate is really as unhealthy as ever is shown by the visitors to it who contract malaria in about ten days... finally, out of 39 _H. willmanni_ captured in the lines, 4, or 21%, had malaria 2 with zygotes, 3 with sporozoites and 1 with both zygote
The author further examined an estate in which 10 grains of quinine were given in the most thorough and systematic manner to each adult who worked, and 20 grains to those who did not work, and 5 grains daily to children, with double doses when they were ill. The blood of 29 children was examined, and the parasites were found in 27.6% of these; while out of 125 adults the parasites were found in 18.4%, giving a total of 20.5% infected out of 154 persons. The author observes that quinine has little effect on the gametids; that patients "die even after 40 grains of quinine daily," and repeats my teaching regarding the persistence of the sporids (Chapter IV); but adds: "If as has been shown, the immunity from malaria produced by quinine leaves the patient infective while he is acquiring the immunity, then it will be impossible, in the presence of many Anophelines, and in the presence of many new arrivals (such as newly-born children), ever to eradicate malaria by quinine. It follows, too, that if drainage be an alternative, even though much more expensive, drainage must be the method which should be adopted. Even if the community possesses no money for drainage, money might be borrowed with which to carry out the works, and at the end there would be an asset to show for the expenditure. Borrowing, however, would be impossible if the object were to buy quinine. It must not be forgotten, too, that the administration of quinine in effective doses is by no means an inexpensive method. To give 10 grains daily to one thousand people, without any extra to those who actually have pyrexia, for ten years would cost about £1,900. Such a sum, if lent by a government to a community at a reasonable rate of interest, would free a very large area from malaria if drainage methods suitable to the local Anophelines were employed. And in ten years the community would have nine years of prosperity and health in which to repay the loan. In the case of many small villages, it would probably be possible to eradicate the breeding-places of Anophelines, where they are in the midst of the community, at a mere fraction of the..."
money which would be required to dose the population effectively with quinine, even for a year. While for other communities the cost of drainage would be relatively much less than in the case of the smaller ones, since the same expenditure would protect a relatively larger number of people." (section 39).

The author carefully compares the conditions in Italy with those in his country. The reason for the freedom of the hills in Italy from malaria is that the principal carrier there is a pool breeder and not a stream breeder. The attitude of the Italians to quinine is due to local conditions, drainage being difficult in many malarious localities there, especially along the coast. But as regards the tropics, the author adds: "It seems only the vision of a dream that any organisation will ever induce a whole tropical population to take quinine in the doses required by the Italians. And when it is further considered that the population, even when taking this quinine, would still be infectious, the policy of spending money on quinine for an indigeneous population, where drainage is possible, appears to me indefensible either on medical or financial grounds." (section 39).

The author also discusses malaria in India, and criticises the statements of James and Christophel (Lancet, 20th June 1909). He does not agree with them that "prevalence of Anophelines, though always important, is by no means in every case the most important factor to be considered," or that the Italian measures are most suitable in India. He states that the Malayan experiences should apply also to India, and adds: "The logical conclusion therefore seems to me that quinine can never do more than give a temporary relief to India, and that the factor to be dealt with is the Anophelines, and that measure must be aimed at it—not only in towns, but also in our districts." For *N. niilusii* he advises closed subsoil drains.
Prevention of Malaria in Formosa.—The island of Formosa, which came under Japanese rule in 1895, lies between Lat. 21° 41' and Lat. 25° 37' N., and between Long. 119° 18' and 122° 6' E., comprising an estimated area of 13,434 square miles. The following are the numbers of the population, according to the latest investigation:

<table>
<thead>
<tr>
<th>Population Group</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formosans</td>
<td>1,470,567</td>
</tr>
<tr>
<td>Aborigines</td>
<td>12,151</td>
</tr>
<tr>
<td>Japanese</td>
<td>82,779</td>
</tr>
<tr>
<td>Foreigners (including Chinese)</td>
<td>12,151</td>
</tr>
<tr>
<td>Total population</td>
<td>1,635,639</td>
</tr>
</tbody>
</table>

Malaria prevails over nearly all localities of the island, and the deaths caused by malaria in 1900-1908 are given below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths from Malaria</th>
<th>Total Deaths</th>
<th>Per 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906</td>
<td>2,354</td>
<td>12,073</td>
<td>104.62</td>
</tr>
<tr>
<td>1907</td>
<td>1,615</td>
<td>11,638</td>
<td>109.17</td>
</tr>
<tr>
<td>1908</td>
<td>1,274</td>
<td>11,274</td>
<td>113.71</td>
</tr>
</tbody>
</table>

Statistics only for the years 1900-1908 are given above, no available ones being obtainable for the preceding years.

It must be remembered that there are still about 1,800 native practitioners of the Chinese school in the island, whose service is scarcely to be depended upon.

(2) Mosquitoes which carry the parasites.—Seven species of
Anophelina are known to be in existence in Formosa, with an additional one recently discovered; they are as follows:

1. Anopheles (Mylekhynchus) sinensis Wied.
2. Anopheles (Myleomyia) Liston.
3. Anopheles (Mycopsis) Liston.
4. Anopheles (Mycyanites) Liston.
5. Anopheles (Mycyanites) Walk.
6. Anopheles (Mycyanites) Theobald.
7. Anopheles (Mycyanites) Theobald.
8. Anopheles (Mycyanites) Theobald.

Of these, the first two species have been found to be the medium of malaria. According to the announced results of experiments made by the late Dr Kinoshita and Dr Miyajima and others, Anopheles sinensis has the power of developing the Plasmodium vivax of tertian fever, but not the Plasmodium vivax of tertian fever; while Anopheles liston is the host of Pl. praecox, its cysts growing upon the mucous intestinal wall. In other words, tertian fever is transmitted by Anopheles sinensis, and acsivo-autumnal fever by Anopheles liston. Anopheles rossii being recognised as an innoxious species, no cyst of Plasmodium can be found growing in its body by process of infecting experiments. The pathogenical importance of other Anophelinae are not yet clearly defined.

In the order of the extent of prevalence, Anopheles sinensis, the tertian fever carrier, comes first; and next comes An. liston, a much smaller but extremely dangerous species. An. rossii is mostly found in the middle and south of Formosa, its sphere of influence in the north being limited to 24° N. The newly discovered Anopheles from Taito (on the east coast) was like wise collected in the southern part. The remaining three species of Nyssorhynchus are met with in the mountainous districts. The newly-discovered An. oki has been obtained in Keelung, which lies 18 miles north of Taito.
A. By the general improvement of sanitary conditions in towns and in the country, as, for instance, by the construction of properly macadamised and paved roads, the discontinuance of the use of the drinking-water mixed with sewage, the facilitating of the carrying-off of rain-water and drainage, and so on.

B. Protection from mosquito attacks by means of wire-gauzed shutters and windows, and mosquito-nets, etc., etc. This means is chiefly adopted by the garrison troops here.

C. Prophylactic administration of quinine after R. Koch.


(4) Results.—As a marked result of the above-mentioned public measure A., Tainan and Tashu, which formerly used to be malaria-stricken places, are now found completely cleared of the dreaded disease. As to the merit of the mechanical measure B., reference may be made to the uniformly improved health condition among the troops of Formosa. The measure of screening the barrack windows, etc., with wire-gauze was first resorted to by the garrison here in the summer of 1909.

The following Table shows its result:—

### Table I

<table>
<thead>
<tr>
<th>Year</th>
<th>Malaria cases per 1,000 soldiers</th>
<th>Malaria deaths per 1,000 soldiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1897</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td>1898</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
<td>1899</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1900</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1901</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1902</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1903</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1904</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1905</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1906</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1907</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>1908</td>
<td>115</td>
<td>1</td>
</tr>
</tbody>
</table>
The unusual increase of the number of malaria-affected soldiers in the last year is accounted for by the fact that in the said year many soldiers fell victims to malaria during the big campaign against the savages, and that the sick rate adopted by the Army was rather too high.

As a result of the medicinal measure C, the experiment made at Kosenpo may profitably be referred to.

Kosenpo is a village lying in the southern mountainous districts, the majority of whose inhabitants are camphor collectors.

In April 1907 malaria prevailed terribly in this locality, especially among Japanese new-comers, so that 30% of the Japanese residents proved to be malaria patients. From July 1907 R. Koch's gramme-prophylaxis began to be systematically used under the direction of the late Dr Kinoshita. The people were administered quinine hydrochlorate in pastil, in pro dosi 10 for adult, every nine and ten days successively. The prophylaxis was strictly conducted under care of the police officials from July to November 1907, and from January to October 1908. The reduction of both malaria-morbidity and malaria-mortality will clearly be seen from the following Table I.

No estimated costs for the prevention of malaria can be given, as they differ according to various circumstances.

NOTE BY R. Ross.—By the kindness of Professor Dr Kitasato, Dr M. Miyajima of his Institute for Infectious Diseases at Tokio has supplied me with the malaria statistics of the Imperial Japanese Army, serving in Japan, China, Corea and Manchuria, as given by the Medical Bureau of the Army. The totals for three years are as follows—

<table>
<thead>
<tr>
<th>Years</th>
<th>Total Patients</th>
<th>Total Deaths</th>
<th>Malaria Patients</th>
<th>Malaria Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906</td>
<td>77,100</td>
<td>749</td>
<td>7,271</td>
<td>10</td>
</tr>
<tr>
<td>1907</td>
<td>104,266</td>
<td>2,717</td>
<td>9,809</td>
<td>6</td>
</tr>
<tr>
<td>1908</td>
<td>114,794</td>
<td>6,400</td>
<td>10,666</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>306,950</td>
<td>10,536</td>
<td>29,746</td>
<td>26</td>
</tr>
</tbody>
</table>

Dr Miyajima says that in Japan itself the parasite is almost exclusively P. vivax, but that the other species occur in Formosa and the Loa Choo Islands. The largest number of malaria cases were in Formosa and in Corea (6,448 and 2,677 cases respectively in the three years).
### RESULTS

**TABLE II.**

<table>
<thead>
<tr>
<th>Months</th>
<th>Japanese inhabitants</th>
<th>Malaria cases per 1,000 Japanese</th>
<th>Malarias deaths per 1,000 Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>374</td>
<td>34</td>
<td>127</td>
</tr>
<tr>
<td>Feb.</td>
<td>305</td>
<td>37</td>
<td>144</td>
</tr>
<tr>
<td>March</td>
<td>901</td>
<td>288</td>
<td>1,257</td>
</tr>
<tr>
<td>May</td>
<td>215</td>
<td>80</td>
<td>164</td>
</tr>
<tr>
<td>June</td>
<td>260</td>
<td>20</td>
<td>405</td>
</tr>
<tr>
<td>July</td>
<td>155</td>
<td>6</td>
<td>242</td>
</tr>
<tr>
<td>Aug.</td>
<td>124</td>
<td>8</td>
<td>144</td>
</tr>
<tr>
<td>Sept.</td>
<td>106</td>
<td>6</td>
<td>134</td>
</tr>
<tr>
<td>Oct.</td>
<td>192</td>
<td>14</td>
<td>228</td>
</tr>
<tr>
<td>Nov.</td>
<td>1,329</td>
<td>12</td>
<td>1,593</td>
</tr>
<tr>
<td>Dec.</td>
<td>1,826</td>
<td>12</td>
<td>2,476</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,320</td>
<td>39</td>
<td>3,967</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Months</th>
<th>Japanese inhabitants</th>
<th>Malaria cases per 1,000 Japanese</th>
<th>Malarias deaths per 1,000 Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>1,484</td>
<td>37</td>
<td>270</td>
</tr>
<tr>
<td>Feb.</td>
<td>1,244</td>
<td>27</td>
<td>195</td>
</tr>
<tr>
<td>Mar.</td>
<td>1,525</td>
<td>36</td>
<td>177</td>
</tr>
<tr>
<td>Apr.</td>
<td>215</td>
<td>8</td>
<td>144</td>
</tr>
<tr>
<td>May</td>
<td>260</td>
<td>20</td>
<td>405</td>
</tr>
<tr>
<td>June</td>
<td>155</td>
<td>6</td>
<td>242</td>
</tr>
<tr>
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<td>124</td>
<td>8</td>
<td>144</td>
</tr>
<tr>
<td>Aug.</td>
<td>106</td>
<td>6</td>
<td>134</td>
</tr>
<tr>
<td>Sept.</td>
<td>192</td>
<td>14</td>
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<td>12</td>
<td>1,593</td>
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<tr>
<td>Nov.</td>
<td>1,826</td>
<td>12</td>
<td>2,476</td>
</tr>
<tr>
<td>Dec.</td>
<td>1,848</td>
<td>12</td>
<td>2,517</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,144</td>
<td>37</td>
<td>3,967</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Months</th>
<th>Japanese inhabitants</th>
<th>Malaria cases per 1,000 Japanese</th>
<th>Malarias deaths per 1,000 Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>1,574</td>
<td>42</td>
<td>270</td>
</tr>
<tr>
<td>Feb.</td>
<td>1,295</td>
<td>27</td>
<td>195</td>
</tr>
<tr>
<td>Mar.</td>
<td>1,524</td>
<td>36</td>
<td>177</td>
</tr>
<tr>
<td>Apr.</td>
<td>215</td>
<td>8</td>
<td>144</td>
</tr>
<tr>
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<td>124</td>
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<tr>
<td><strong>Total</strong></td>
<td>7,279</td>
<td>37</td>
<td>3,967</td>
</tr>
</tbody>
</table>

(= indicate prophylacted months)
Notes on Some Other Works — It is impossible to give within the limits of this book a full account of all the campaigns which have been commenced, or even to mention some of them; but I think that brief notes on the following works should be added.

(1) India.—In section 7 I described my own work in India up to the publication of a report (1899) in which I suggested my proposals for mosquito reduction. By this time I had left India; and no notice was taken of the report, except that several medical men wrote against the idea. They pointed out that Anophelines breed in rice-fields, and so on, near cantonments, and therefore thought that the task of banishing them would be impossible. They evidently failed to understand my arguments, and had no idea of the economical principle laid down in axiom 3 of section 38.

At this time many persons were writing up the recent discoveries. Unfortunately, some of them were not personally acquainted with the tropics, and few of them had any knowledge whatever of practical tropical sanitation. It was almost impossible to make them understand my proposals; but some of them clamoured for a formal experiment to test them in the field. I was very averse from this suggestion. Success would demand a long and patient inquiry, requiring an exact preliminary survey of the amount of malaria and the number of mosquitoes present, followed by equally exact measurements of these quantities made on frequent occasions. Now it will be seen from Chapter V how difficult it is to measure malaria
exactly, and how much more difficult to obtain any direct enumeration of the Anophelines. Moreover, failure might be due, not only to the impracticability of my proposals, but also to want of enthusiasm or care in those who were appointed to test them. Then failure, or at least an unsatisfactory result, was very probable, and would have a disastrous effect upon anti-malaria work for many years. I thought it would be much better to allow local authorities to attempt the work quietly in the ordinary course of sanitation, and not as a formal "test experiment; and this was actually done since 1902 in Havera, Ismailia, the Federated Malay States, and elsewhere.

But my critics could not be got to understand the bad policy of their suggestions, and consequently the so-called test experiment was commenced at Mian Mir, near Lahore, Punjab, India. The place was a most unsuitable one: almost flat, with an impervious subsoil and watered by irrigation. Mosquito reduction was not easy in it. Moreover, it was a military cantonment containing scattered barracks, from which statistics of the local malaria rate could hardly be compiled, since the troops and their followers were frequently being changed from other stations; while, lastly, the place was scarcely a town, that is, a locality which was most appropriate for mosquito reduction. In fact, the selection of the place showed how little the subject was understood at that time.

Mian Mir was examined by the Malaria Commission of the Royal Society in 1902, but without any exact estimates of the amount of malaria or the number of Anophelines. In April 1903, however, practical operations were at once commenced, evidently on the model of my suggestions for Sierra Leone, and were continued for that and the following year. For 1902 the operations were reported upon by S. P. James [1903], and for the following year by S. F. Christophers [1904]. The former reported very doubtful success; and the latter practically denied the feasibility of mosquito reduction. Their reports were, however, exhaustively criticised by myself in a paper.
NOTES ON SOME OTHER WORKS

[1904], to which no reply has been given; and also by Sewell [1904], Giles [1904], and others.

No one who is acquainted with the nature of scientific evidence can imagine for a moment that this experiment gave any proof of anything connected with the subject. The measurements of malaria were of the most inadequate nature, and were based upon the most insufficient random sampling—while in some cases the number of children examined was not recorded (section 31 (8)). The enumeration of mosquitos was evidently of an equally casual nature, the authors not having been able to devise any accurate method. Neither report was well written, and the second one was worded so confusedly that almost anything might be inferred from it. Both reports claimed that the mosquitos increased in spite of the reduction measures. This is, of course, possible to a certain extent (section 29 (8)); but it is otherwise mathematically impossible, and the statement suggests only that the authors' methods were inaccurate. As no exact enumeration of the mosquitos had been made before the operations, the total result of the work could not be determined. In fact the reader who is interested in exact work will do well to compare these reports with Chapter VI, if only to learn what not to do as regards the measurement of malaria and of mosquitos, and the conduct of a campaign.

It has been frequently claimed by several Indian writers on the prevention of malaria, that the operations at Missir M ir were carried out merely to determine the practical feasibility of mosquito reduction for a reasonable cost in India. Even this claim cannot be accepted. During the first year (1902) only 7,216 rupees were expended for dealing with an area of 4 square miles containing numbers of troops, and of this sum, 5,984 rupees were spent on brickling, lining and plastering a single watercourse, leaving only 1,232 rupees, or about £120 for the rest of the work. This is hardly a convincing expenditure for a test experiment. The life of a single soldier
costs more. It will scarcely be believed that in the second report of the experiment, designed, as has been declared, for the express purpose of providing official information for the whole of India, no accounts whatever of the cost incurred were vouchsafed! In fact, the whole affair was conducted on un­
practical and unscientific lines. It proved nothing at all, and its only effect was to retard anti-malaria work in that and other countries for years.

Since 1904 the military authorities at Mian Mir undertook much more patient and useful work there, with the apparent result of a considerable reduction in malaria—see especially H. D. Rowan (1908). At the Bombay Medical Congress of 1909, however, S. P. James described how, during a recent visit to Mian Mir, he had found no reduction, either in the malaria or in the number of mosquitoes. His statements were immediately controverted by five administrative medical officers (see Lancet, 3rd July 1909). James stated that out of ten men of the Gloucester regiment, who had been taking quinine regularly, and who were selected by him at Mian Mir "more or less at random," he found parasites in no less than eight—an enormous percentage. The commandant of the regiment, however, informed me at Bombay shortly afterwards that his regiment had not suffered much from malaria at that time.

Many local campaigns have been commenced in India, and will be found mentioned in the Annual Sanitary Reports, in the Proceedings of the Malaria Conference (1902), and in a recent publication by W. G. King (1909), and elsewhere. I have received many private communications regarding these, from which I gather that they have not been given much encouragement from headquarters, that the organisation has not been sufficient to ensure continuity, and that the necessary measures of malaria have been quite inadequate. There is no doubt that the general policy of a clique in India has been opposed to mosquito reduction, and has not been very keenly interested in any other form of malaria campaign.
NOTES ON SOME OTHER WORKS

...
it appears at first sight to put them to no expense. We generally observe two things about tropical municipalities—the excellence of their sanitary laws and the completeness with which the public ignores them. Which is the cheaper in the end, (a) to make one inspection and then do the work, or (b) to make many inspections, worry the householder, issue several summonses, be finally forced to do the work, and then try to recover the cost in the law courts? We must always remember this question, and endeavour to arrange a proper balance between the respective obligations of the householder and the municipality.

(a). Hongkong.—One of the earliest and best of the campaigns in British territory. The city of Victoria, usually called Hongkong, runs for nearly 5 miles along the north of the island of that name at the mouth of the Canton river in South-East China. The island, 13 miles long and from 2 to 5 miles broad, consists of a broken ridge of hills, rising to nearly 2,000 feet, and the city is built on a hill sloping down to the water, some of the terraces and houses being 500 feet above sea-level. There is also a large residential district on the mountains reached by a cable tramway. The soil is granite. All along the face of the hill on which Victoria is built there are beds of streams, known as "nullas," which used to swarm with Anopheline larvae. The population of the colony was 377,850 in 1905, of which 10,835 were whites (nearly half belonging to the British Army and Navy). The rainfall is from 70 to 80 inches a year. Malaria has been always very prevalent here, and I remember that in 1881 the colony was cited as an example of the telluric miasma due to decaying granite. The first researches on the new lines were commenced as early as May 1901 by Dr. J. C. Thomson [1902], who undertook an exhaustive study of the mosquitoes and their breeding-places. He examined over 32,000 specimens, of which he found about 4\% to be Anophelines, and in November advised an active anti-malaria campaign by drainage,
clearing of jungle, "training" of the nullas, the use of wire-gauze, oiling pools, and quinine prophylaxis. As seen by his excellent papers [1900-1903], his recommendations were not of a general nature, but were particular, practical and exact.

These recommendations were rapidly acted upon by the Government. Since 1901 all the nullas or watercourses within and near the city were "trained"—that is, rendered smooth and even that the Anophelines could no longer breed in them; and much similar work was done wherever most needed elsewhere by training watercourses, buying up rice-fields, and so on. The details of the campaign are so numerous that it is impossible to give them here. They will be found in the publications given in the bibliography and in a good paper by Mr J. M. Young [1901], who took part in the early stages of the work. The results are given in the annual sanitary reports of the colony, and in a recent address by the medical officer of health, Dr Francis Clark [1906]. Dr Thomson informs me that before estimating them it is necessary to remember that malaria can never become extinct in Hongkong owing to the fact that some three thousand to four thousand natives come and go from and to the country districts every day, and that a number of these will remain infected in spite of all local measures. Nevertheless, the figures show a rapid diminution both in the admission and in the death-rates.

### Malaria Statistics in two large hospitals

<table>
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<tr>
<th>Years</th>
<th>1897</th>
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<th>1900</th>
<th>1901</th>
<th>1902</th>
<th>1903</th>
<th>1904</th>
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<td>Deaths</td>
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### Admission Rate of Police for Malaria

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<tr>
<th>Years</th>
<th>1896</th>
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<th>1898</th>
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### Deaths from Malaria

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<tr>
<th>Years</th>
<th>1895</th>
<th>1896</th>
<th>1897</th>
<th>1898</th>
<th>1899</th>
<th>1900</th>
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<th>1902</th>
<th>1903</th>
<th>1904</th>
<th>1905</th>
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<tbody>
<tr>
<td>Population</td>
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<tr>
<td>Total deaths</td>
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<td>332</td>
<td>332</td>
<td>332</td>
<td>332</td>
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<td>332</td>
<td>332</td>
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<tr>
<td>Deaths in city (Chinese only)</td>
<td>132</td>
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The official sanitary reports give similar figures. The improvements have, of course, varied much in different localities. Thus in 1900 the western end of Bonham Road used to be one of the worst districts. Now, in 1905, it is reported not to have sent a single case to the Government Civil Hospital.

With regard to cost, Dr. Clark reports that up to the end of 1905 the Government had expended about £5,000 on anti-malaria measures, and estimates that £6,500 would be spent by the end of 1906—a small amount to pay for the good that has been done. The campaign in such a thickly populated district must be difficult. Figures for subsequent years have not been obtainable.

Candia, Crete.—The accounts of this excellent campaign, conducted in connection with the British troops in Crete, will be found in successive numbers of the Journal of the Royal Army Medical Corps. The town of Candia, containing 21,000 inhabitants, is situated on the west shore of a semicircular plain bounded by hills. The rainfall is heavy, and the ground is traversed by many streams, which become torrents in winter and nearly dry in summer. Two of them have marshy margins near the sea. The houses of the town are of the Oriental type and contain many wells. The troops are accommodated in quarters to the west of the town and close to it, and suffered considerably from malaria. Apparently as early as 1902 Lieutenant-Colonel J. V. Salvage, R.A.M.C., commenced to examine into the distribution of Anophelines and to destroy the larvae by drainage, or by closing or filling the wells, or putting fish into them, and expressed himself hopefully regarding the result. In March 1903 Major C. J. MacDonald arrived in Crete and continued the work. He gives many very interesting details. Work of a permanent nature were attempted, and quinine prophylaxis and mosquito nets insisted upon. The first results were as below—
<table>
<thead>
<tr>
<th>Years</th>
<th>1901</th>
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<tr>
<td>Strength</td>
<td>224</td>
<td>280</td>
<td>327</td>
</tr>
<tr>
<td>Admissions</td>
<td>1,540</td>
<td>1,684</td>
<td>1,287</td>
</tr>
<tr>
<td>Rate</td>
<td>273</td>
<td>226</td>
<td>59</td>
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The admissions include simple continued fever, together with malaria, in order to avoid error due to diagnosis. Major MacDonald attributes the fall to the measures taken in 1903. Captain R. A. Cunningham, R.A.M.C., adds a third article in which he stated that the fall in the malaria rate had continued, and was only 97% in 1904 compared with the 33% of 1903. The mosquitoes were so few that it is almost unnecessary to use a net at night. In 1905 there were 246 admissions, at a rate of 387/100. Many men became infected on guards and outposts.
The Prevention of Malaria in War.—Part I. The Lessons of History.—The history of malaria in war might almost be taken to be the history of war itself, certainly the history of war in the Christian Era. Even in Europe up till at least the middle of the nineteenth century all armies in the field were liable to attacks of this class of disease, as witness the French and Austrian armies in the campaign in the north of Italy in the year 1859. It is probably the case that many of the so-called camp fevers, and probably also a considerable proportion of the camp dysentery, of the wars of the sixteenth, seventeenth and eighteenth centuries were malarial in origin. In our own army, as the writings of Pringle and Monro teach us, the various campaigns in the Low Countries were marked by severe outbreaks of paludal fevers, culminating in the epidemic that wrecked the ill-starred Walcheren expedition just one hundred years ago. It would be out of place here to do more than mention these earlier histories, but the Walcheren disaster merits more than passing notice, for several reasons. In the first place, it occurred in comparatively recent years. There must be men still alive who can remember having seen and spoken to survivors of the expedition, some, at least, of whom must have carried the marks of their sufferings to the grave. In the next, the close proximity of the scene of action
THE PREVENTION OF MALARIA IN WAR

...to our own shores struck even contemporaries with a sense of the reality of the disaster. These two characteristics tend to make this outbreak one of peculiar interest; but there are others of even greater value than interest, which bear very closely on the question of prevention of malarial fevers in campaigns of the present day. Of these the first is that the locality selected for the debarkation of the troops was one notoriously unhealthy on account of malarial fevers. Already, in 1747, the force landing in Zealand had suffered to such an extent from this cause that, according to Sir John Pringle, some of the battalions in South Beveland and Walcheren had but 100 men fit for duty, being less than one-twelfth part of their whole number. Another experience repeated in the expedition of 1809 was that the men-of-war which lay at anchor in the channel between South Beveland and Walcheren, even during the worst period of the distemper, were not affected with either flux or fever, but enjoyed the most perfect health. In the light of our present-day knowledge this coincidence is easy of interpretation; but the practical lesson to be drawn was clear, or should have been clear, even in 1809, namely, that on a malarial coast troops should not be landed from the transports until all steps are ready for an immediate advance. It was the preliminary delay under the walls of Flushing that laid the army of Lord Chatham open to the first onslaughts of disease. An early advance into the comparatively higher ground of the interior would undoubtedly have done much to check the disease. In the second place, the season of the year selected for the expedition was notoriously the most unhealthy of the year. And this fact also was on record. Sir John Pringle wrote as follows in the year 1765: "The epidemics of this country may therefore be generally dated from the end of July, or the beginning of August, under the canicular heats; their sensible decline, about the first falling of the leaf; and their end, when the frosts begin." Here, again, the lesson was as plain as the warning. If a force has to land in a malarious locality then the unhealthy season...
should be carefully avoided. How long it took before that
lesson was learnt the records of our earliest campaign in
Asiatic, and the experiences of the French in Madagascar,
show only too clearly. And lastly, there was no selection of
the men. Davis, who was appointed to attend the troops on
their return to England, in his "Scientific and Popular View of
the Fever of Walcheren" (p. vii.), alludes to the fact that the
troops consisted of "numbers of young men unaccustomed to
fatigue and the hardships of a military campaign." It may be
accepted as one of the most important points in the conduct
of a campaign in a malarial locality that the men should
be seasoned soldiers, free from the taint of previous severe malarial
infection, but accustomed by experience to the proper camp
discipline essential to the prevention of paludal diseases.

The expedition left the shores of England on the 28th July
1809, and disembarked in Middleburg and Walcheren on the
29th and 30th of the same month. The siege of Flushing was
at once undertaken, and this place surrendered on the 15th. Up
till that date, with the exception of the men killed in action,
there had been no deaths in the force of 17,000 men, and
though the medical authorities on the spot were justifiably
anxious, in view of the medical history of the locality, the
general public were far from sharing in this apprehension,
observing that the notion of the unhealthiness of Walcheren
being so great that it ought not to be garrisoned by British
troops, was too absurd to deserve much notice: as it might
probably be as unhealthy as Romney marsh, or the hundreds
of Essex. 1 This was on the 23rd August, but "a different
impression was felt in Walcheren, for as early as the 25th it
appears, by a letter from the expedition, that the interruption
to active operations which had then taken place from the
rapidity with which the disease was spreading had caused much
regret." 2 By the 29th August there were 3,000 men in hospital
out of a total of about 25,000 men. Early in September there

1 Davis, p. xi.
2 Ibid. p. xi.
were upwards of 7,000 men in the different hospitals, and by the 13th it was estimated that out of a strength of 15,000 in Walcheren, 10,000 were actually sick; the deaths then averaging at from 25 to 30 per day. The repatriation of the troops to England had already begun, and "about the 13th they began to arrive at Deal, where soon after the mortality in one hospital amounted to 14 in one day ... indeed the mortality among those who first arrived in England was greater, comparatively, than at the same period even in Flushing; for there the whole daily mortality, though seldom less than 50, for some time previous to the 12th had never on any one day exceeded 100."

At the latter place, "on the 23rd of September, the sick report included 218 officers, 382 sergeants, 190 drummers and 3506 privates." From that date the fever subsided. On the 26th there were 9798 in hospital, and on the 30th 8600, and though the army was disabled and vanquished, its invisible enemy gradually slackened its pursuit, and the "remnant of an army returned to England on the 23rd December, having faced fifteen days' fighting with 247 casualties, and two months' fever with more than 4000 dead. And how about the wounded in this appalling struggle? Years afterwards the men who survived still showed in shattered constitutions the results of the ineptitude which planned, and the inefficiency which led the expedition of 1809.

The expedition to Walcheren is one of the most striking instances of the part that epidemiology should play in strategy. There were, on political and military grounds if on no other, doubts as to the advisability of attacking the French in the Low Countries. The known unhealthiness of Zealand should have been recognised, and should have acted as the decisive factor. In whatever part of the French dominions a British force had been landed, at that season of the year, the neighbourhood of Walcheren was the last that should have been selected.

1 Davis, p. xxxi. 2 Ibid, p. xxxii.
In no other campaign during the "Great War" did malarial fevers play so commanding a rôle as in the expedition of 1864, though it is true that both in Estremadura and before Ciudad Rodrigo, the army under Sir Arthur Wellesley suffered notably from this type of disease. The chief interest, however, of paludism attaches historically in the nineteenth century to campaigns in the tropics, and as this will undoubtedly be even more the case in years to come, I do not propose to refer in this brief sketch to any other class of enterprise. And I will further limit myself to a consideration of two of our own expeditions to Ashanti, and to that of the French to Madagascar in 1895, since these present typical instances of small wars where success or failure depended not on the bravery of the men, or the tactical skill of their leaders, but entirely on the amount of forethought paid to the problems of disease at home, and to the translation of that forethought into terms of energetic action on the spot.

Passing over the earlier unsuccessful, or only partially successful campaigns of 1822, 1824 and 1833 in Ashanti, I shall begin with that of 1864. Of this expedition the late Surgeon-General Gore (sanitary officer with the expedition of 1873) writes ("Medical History of our West African Campaigns," p. 10): "It can scarcely be called a war, as an enemy was never seen, or a grain of powder expended; our troops were defeated by disease, much of which was preventable." He goes on: "In August of the former year (1863), the right wing of the 4th West India Regiment landed at Cape Coast Castle. Preparations were at once commenced for the future advance. Stores were collected and paths cut, these operations lasting until December, during the continuance of which the men suffered much from dysentery, remittent and intermittent fever."

This point is worth noting. One of the most essential precautions in the case of tropical campaigns is to see that the collection of stores is carried out in anticipation of the landing of the expeditionary force. The campaign, as already stated,
was a fiasco. By the end of March one quarter of the strength was in hospital, and by the middle of May all the members of the original force at Prathra were relieved. The admissions in 1864 amounted to over 1,600, and the deaths to a fraction under 60 per 1,000. It must be noted, too, that these troops were not Europeans, but black troops from the West India regiments. Of 60 European officers 35% succumbed to the effect of disease. The lessons of this campaign were not, however, lost.

Early in 1873 the Ashantis made one of their periodical forays into the Gold Coast Protectorate. Owing to the scanty numbers and scattered distribution of the British garrison, our men were confined to the defence of the posts held by them. A small reinforcement of Marines was despatched from England, and reached Elmina, the most seriously threatened post, by the 12th June, inflicting on the next day a serious repulse on the enemy. Affairs remained in these penes, the enemy becoming somewhat less active, but still maintaining a threatening attitude, until, in September, an attack on the boats of the Rattlemake demonstrated that sterner measures must be taken to deal finally with them. Sir Garnet Wolseley arrived from England on the 2nd October, and at once began the erection of wooden huts, and the enlistment of native artificers, labourers and porters, as well as the enrolment of local levies and regiments under specially selected officers: "it having been thought that with European organisation and guidance Ashanti armies might well be successfully encountered by Africans of other races." The first blow was struck on the 14th October, when a force advanced from Elmina and captured and burnt the village of Essaman, with but trifling loss. As a result of this blow the Ashantis prepared to retreat to their own country, but Sir Garnet decided that to complete their punishment a force containing a strong European contingent should be sent into Ashanti territory. In spite of well-founded apprehension as to the consequences of employing European
troops in the climate of the West Coast, it was decided that a force corresponding to the requirements formulated by General Wolseley should be despatched, it being considered, as a result of the experience of campaigns in low-lying, swampy districts of other tropical countries, that "there was a reason of comparative healthiness corresponding to the coldest season of the year, and that in this, with suitable precautions and limitations, Europeans might undertake field service in the Gold Coast country." Pending the arrival of the European force operations were undertaken with the troops at hand with a view to clearing the enemy from the territory of the Protectorate, and facilitating the advance of the punitive force as far as the banks of the Prah. Sites were selected between the base at Cape Coast and the river named, for the formation of camps, temporary barracks being erected at these places. In all, eight such sites were fixed, the average distance between one camp and the next being a fraction over nine miles. The object in view was to ensure that "the troops were to march into stationary camps, and to reach the Prah—the second base of the expedition—as little fatigued as possible, so that the force might start thence with the men in the highest state of efficiency, and strike the intended blow before it was materially reduced by sickness." Eventually, the first detachment of European troops landed on the 1st January 1874, and the whole strength was assembled and the river crossed on the 21st. Some rather smart fighting occurred at Amoaful on the 3rd January, and again outside Coomasie on the 4th February. The city was entered that evening, and burnt and evacuated on the 6th. The entire force, with the exception of some of the irregular corps, recrossed the Prah by the 14th February, that is, within three weeks of the date of first crossing it. The 42nd Highlanders, which was the first regiment to land, was also the last to leave. The period that elapsed between landing and embarkation was eight

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1 A.M.O. Report, 1873, p. 176.  
2 Ibid. p. 186.
weeks all but one day. The admission rate was 58 per 1,000 for European rank and file, and the death-rate 18·2 per 1,000. Five British officers and 13 men were killed in action, while 21 and 40 of these two classes respectively died of disease. This striking contrast between the two campaigns of 1864 and 1874 deserves to be noted. The keynotes of success in the latter case were careful preliminary preparation, and swift and rapid execution. Failure in the former expedition was due to "unselected men, under officers many of whom had already suffered from illness, not especially well equipped or cared for, remaining in the field at a bad season, and languishing in inaction month after month."

The only other historical instance on which I shall dwell is the French campaign in Madagascar in 1895. The necessity for an expedition to Madagascar was recognised in the late months of 1894, but already for a year prior to the actual parliamentary sanction for the despatch of a force, the Naval and War Departments had had such a possibility under consideration, and the former had, with commendable forethought, caused reconnaissances to be made of the possible points of disembarkation, and of the best lines of advance. In August 1894, an inter-Departmental Committee was formed at the Foreign Office, in which the two departments already named and the Colonial Office collaborated in the production of a joint report on the geographical and military situation, with suggestions as to the composition of the expeditionary force, and the various measures to be adopted to meet the grave difficulties presented. There was in fact no want of preparatory consultation. About the middle of November it was decided to entrust the execution of the plans to the Ministry of War, and accordingly a fresh commission was formed, of an advisory nature, which sat at the War Office under the direction of the Chief of the General Staff, and was presided over by General Duchesne, specially selected for the chief command of

Meanwhile, time passed. It was necessary to start active operations by May at the latest, and in fact the advance guard of the expedition landed at Majunga twenty-four days before the last-named commission completed its work. Even so, the War Office was by no means independent in its management of affairs. Diplomatic arrangements still remained under the Foreign Office, while the troops available came partly under the Ministry of Marine, partly under the Colonial Department, and partly under the War Office. As one result of the complication of authority and responsibility the force was compelled to march for forty-three days through a malaria-infested country, instead of proceeding by steamer, though the necessity for the latter expedient had been recognised, and arrangements to that end begun. Transport being deficient and unsuitable, the troops were forced to advance in heavy marching order, in spite of the heat. Medical equipment was left behind, and even quinine was often not to be had. No special huts were provided, and Malagasy huts had to be utilised even at the very base. From the 1st to the 24th March the troops were almost entirely occupied in disembarking matériel, in building shelters and making roads, work made all the more laborious by the lack of native labour, and the heavy rain.

Eventually the supply of water at Majunga ran short, the apparatus for distillation being insufficient, and an advance had perforce to be made. One company of engineers that left Majunga 225 strong, arrived at Suberbieville with only 25 worn-out men still effective. It is unnecessary to prolong this narrative. Reynaud gives in his excellent *Considerations...* 1

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1 Reynaud, p. 312.
Sanitaires sur l’Expédition de Madagascar," a detailed account of the misfortunes that continued to befall the expedition. From Suberbieville a flying column was despatched to Antananarivo, which it reached on the 30th September after incredible exertions, leaving ten per cent. of its strength on the road. The French soldiers christened this column "la colonne Marche-Ou-Crive," a not inappropriate expression for a force where to fall out meant mutilation and death at the hands of a cowardly enemy. And yet many fell out and remained to die of starvation, worn out with suffering and illness. And as Dr Reynaud reminds us, this was the march of a conquering army, not a precipitate flight before a victorious enemy, but the culminating point of an expedition, the details of which had been carefully thought out. The last remnants of this unfortunate army left the shores of Madagascar on the 28th December, leaving behind them 4,498 dead out of the combatant force alone. Amongst the auxiliaries it was estimated that there were 3,000 deaths, whilst as regards non-combatants the numbers are beyond calculation. The proportion of deaths amongst the combatants was equivalent to 320 per 1,000 of strength, due almost entirely to malarial fevers and their sequelae. The deaths in action were 13, and in addition there were 88 men wounded. The causes of this disaster were the antitheses of those which led to our success in Ashanti in 1874 — confused councils, divided authority, and delayed execution.

Part II. Practical Measures.—We now come to the important question of the prevention of malarial diseases in war. I propose to discuss this subject under two heads. First, the measures to be adopted in anticipation of the opening of hostilities, and secondly, those to be carried out during the actual progress of active operations.

Measures to be adopted in anticipation of the outbreak of hostilities.—Before actually detailing these, it is necessary to insist on their enormous importance. It is not going too far...
to say that the success of any tropical campaign depends infinitely more on the administrative measures taken in the preparation for the expedition than on the courage and fighting capacity of the troops engaged. The success of the Ashanti campaign of 1874 was ensured in full hall before ever Sir Garnet Wolseley left England, and the fate of the French expedition to Madagascar in 1895 was decided in Paris and not at Majunga or Suberibeville. The only serious problem in a tropical campaign is disease. This has been proved time and again. No soldier will for a moment pretend that either in Burma or Ashanti the fighting was of a serious nature, and the same is true of the French army in Madagascar. The only obstacle to be feared was disease, and most importantly malaria. Now there is this difference between a human enemy and disease. The former may alter his plans at the last moment, and our plans may have to be changed accordingly. But disease does not alter its laws. As far as we know or can guess at those laws we are able to calculate confidently on their regularity, and our plans can be fixed accordingly. It is almost a platitude to say that the success of any tropical campaign is settled as much in Whitehall as on the actual spot. An ill-provided, ill-thought-out expedition can only end in disaster, however brave the soldier, and however skilled his commander. On the other hand, but little military skill and no extraordinary amount of courage is necessary to enable a small picked force of healthy Europeans, armed with modern weapons, to march through the territory of the most powerful savage tribe in the tropics. But what is necessary is that the objective should be clear, the means exactly proportioned to the end, and all things necessary provided before the start is made. It was an observance of these principles that made the Ashanti campaign of 1874 at brilliant success and neglect of them that turned the French expedition to Madagascar in 1895 into a dismal failure.

The composition and strength of the force sent is as
important consideration. One of the greatest initial mistakes made by the French Government in 1895 was sending too large a force, and one in which the proportion of Europeans was unduly great. As already stated, the military foe is the one least to be feared in a tropical campaign. Locally raised troops drilled and officered by Europeans should be capable of meeting their own tribesmen, undrilled, unofficered and poorly armed. A stiffening of Europeans is necessary, but no more. General Gallieni, in his "Deux Campagnes au Soudan Français," lays down this principle very clearly. "Taking into account," he says, "the unhealthiness of the climate and the peculiarly trying conditions that characterise our campaigns in the Soudan, I did not wish to encumber myself with too large a force of Europeans. I contented myself with a strong company of Marine infantry. In action this body would be available as a reserve to the native troops. The right class of soldier for the Soudan is the Senegalese rifleman." The following are the numbers respectively of Europeans and natives employed in some of our campaigns:

- Abyssinia: 3,655 Europeans, 9,833 natives.
- Ashanti (first expedition, 1868), 2,284 Europeans, 2,377 black troops.
- Ashanti (second expedition, 1874), 1,050 Europeans, 2,050 black troops.

It will be noted that the disastrous expedition to Ashanti in 1868 was the only one in which there was an equality in numbers between the two classes. In Madagascar in 1895 the French had 11,000 European soldiers to 3,800 natives (two battalions Algerians, one battalion Malagasy, and one battalion Hausa). It may be definitely laid down that those branches of the service not immediately concerned in fighting should be composed entirely of natives, sufficient Europeans only being sent to superintend their work. This rule applies to the Engineers, the Supply and Transport Departments, and to
a great extent to the Medical Department. Men actually engaged in nursing the sick should be Europeans, but cooks (with a few picked exceptions) and the general duty section generally should be replaced by natives. The composition of the force should be such that no fatigue and no unnecessary non-combatant duties should be imposed on Europeans.

The next point to be thought of is the selection of the men to form the force. These should be carefully picked. All men with a previous history of severe or repeated malaria should be excluded. As regards rank and file this rule should be absolute. No man whose blood contains, or probably contains, the malarial plasmodium should be allowed to proceed on the expedition, partly in his own interests, but mainly in those of his comrades. As regards officers, and more particularly those who possess special qualifications for employment, some latitude must be given. In such cases three or four examinations of the blood should be made, and if plasmodia are not found, a previous malarial history need not exclude. If plasmodia are present, the value of the individual as a strategical or tactical factor must be balanced against his potential danger as a disease centre. With an educated man occupying a tent by himself the danger is obviously not so great as in the case of a comparatively uneducated private soldier sleeping amongst his comrades. No young soldiers should be sent. Not because there is, as far as we know, any special predisposition connected with immaturity, but because the less tough a man is, the less able he is to withstand the hardships and privations inseparable from tropical active service, and, therefore, the more likely he is to break down, and consequently lower his powers of resistance. It must be remembered that in a malarious country a man with plasmodia in his blood is just as much a focus of infection as a small-pox patient would be in a barrack-room at home. Any man, therefore, who is likely to break down is a danger to his comrades, and should be rejected. The made soldier
has the further advantage that he is more knowledgeable as regards the thousand details that make the difference between comfort and discomfort, which in the tropics is almost equivalent to saying health and disease, than the raw youngster. He knows better how to cook, how to rig up rough shelters, what to eat, drink and avoid, and, generally, how to look after himself. Syphilis, of course, should exclude, unless the man has special qualifications. Some German authorities advise that all men should be tested prior to embarkation, to see whether or not they possess any special intolerance to quinine—a somewhat meticulous precaution. An absolute intolerance of this drug is rare, as a matter of experience.

The next point to be considered is the selection of the theatre of war, and more especially the selection of the line of advance into the enemy's country, and the base of operations. As regards the first named, naturally not much can be done by the sanitarian. If the enemy inhabits a malarial country, or the key of the strategic situation lies in a district where these diseases are rife, the fact has to be faced, and made the best of when the time comes. Still the Walcheren expedition is a notable instance where the epidemiological factor should have been given decisive weight. As regards the line of advance and the base of operations the case is different. One of the most important duties devolving on the Intelligence Department, in connection more particularly with campaigns in the tropics, is the collection of information as regards the health conditions of the country to be invaded. If a preliminary reconnaissance is feasible, a specially-selected medical officer should be entrusted with this duty. He should, if possible, be acquainted with the country already, but most certainly he should have a thorough practical knowledge of malarial prevention and of tropical entomology. He should ascertain the spots most suitable for landing troops, and note the possibilities in the way of systematic malarial prevention pressed by each. He should, at the same time, draw up schemes for
such work, giving an estimate of time necessary for its completion, number of labourers required, and so on. His reconnaissance should be pushed as far up the line of projected advance as possible, and he should select sites for camps and posts, temporary and permanent. It must be kept in mind that digging, as we mostly see in these cases, with a savage foe, the first energies of the force should be directed, not against the human enemy, but against the far more intractable and deadly insect foe. Superiority in armament should be more than sufficient to cancel the tactical defects, if any, of a position selected primarily on sanitary grounds. More especially would this be the case if the base were situated (as in the majority of cases it will be) on a coast where the fire from the fleet can be made available to assist the force on land. It would be a mistake, however, to suppose that there need necessarily be any conflict between the sanitary authorities and the staff of the expedition. A good military site is in most cases elevated, and free from immediate obstruction to the view. The post, therefore, will be more or less elevated, and the surrounding jungle must be burnt or cut down, both important points as regards the prevention of malaria. Proximity to drinking-water must not be allowed to overrule the importance of avoiding as far as possible all mosquito-breeding grounds.

The place being fixed, the next point in order of importance is time. Here greater latitude is allowable, and it must be at once stated emphatically that only the most urgent political necessity, the rescue, for instance, of a beleaguered garrison, can justify the despatch of a European force to a malarious country at the unhealthy season of the year. As an instance of this may be noted the Ashanti war of 1873. The first inroad of the Ashanti took place in May of that year, but though the various threatened posts were reinforced as necessary, the first actual blow was not struck by Sir Garnet Wolseley till the 14th October. The Ashanti expedition of
1864 shows equally well the results of neglecting this obvious precaution. It is necessary to insist on this point. The expedition in 1864 was undertaken in the unhealthy season—March to June—and the mortality and sickness, almost entirely from malaria, were so great that the entire enterprise collapsed.

Malaria was just as rife on the coast in 1873 as in 1864; the mortality among the Marines in the interval between May and October of the former year, whilst Wolseley was waiting for the auspicious moment to strike his blow, was 17.50 per 100, greater, as Sir Anthony Home (A.M.D. Report, 1873, p. 223) points out, than that of the army in Walcheren; whilst that of the expeditionary men after October was only 3.14%. It must be remembered that scientific prevention of malaria, as we now understand the term, was as little known in 1873 as it had been nine years earlier. The striking difference in the incidence of disease in the two expeditions was due, in great part, to the careful selection of the season in which active operations were carried out.

The question of housing of troops is most important. For this purpose portable mosquito-proof houses should be provided. These can be constructed of any material, but probably some of the modern fire-proof compositions (Eternit, etc.) would be found the most convenient. These should be provided in sufficient numbers to house all European details left at the base throughout the progress of active operations, with a margin of 10 to 20%. This is essential. No European should be made to sleep exposed to the attacks of mosquitoes for a single night, where this risk can by any possible means be avoided. If the force is kept, as regards Europeans, within reasonable limits, there should be no difficulty in this respect. Any barracks of this nature sent out should be shipped on the transports carrying the troops, and it ought to be laid down that no men should be landed in advance of their barracks. If the line of advance is easy and well known, and if transport is easily procurable, then huts for Europeans should be so
forward to the first camps on the Lines of Communication, especially those likely to be occupied permanently, as in Ashanti in 1873-1874. If the correct view of the class of campaign be clearly recognised, which is, that the contest is one not so much with man as with disease, and that the defensive measures necessary should be directed not against the attack of a human foe, but against those of tropical insects, it will be realised that the provision of adequate shelter against these pests is as essential as the provision of adequate shelter against the fire of a civilized enemy in a European war. The best type of hut or barrack is one raised on piles from the ground, much like the pattern of bungalow used in Burma.

**Rations.**—The scale of rations should be liberal. The meat would probably need to be in most cases preserved, and probably biscuits would have to take the place of bread. In this case a liberal supply of antiscorbutics in the form of lime-juice, pickles, jam or preserved fruit should be supplied. A special issue of coffee, cocoa or tea should be arranged to be served out to men on night duty. It is unnecessary to say that alcoholic stimulants, in excess of the ordinary service occasional issue, are not demanded.

**Clothing.**—The ordinary field service kit would be sufficient, with the addition of gloves and veils for use after dark. The Japanese mosquito-bonnet might be adopted.

**Special equipment.**—For hospitals mosquito-netting should be issued, and the same applies to the details left at the base. It is doubtful how far it is any use issuing squares of curtain to men actually in the field, since the use of it in camp life is difficult. It would at least be a harmless precaution. Some form of mechanically operated fan should be supplied for use in hospitals and offices at the base. The motive power can be supplied either by electricity, or by a small gas or hot air engine. Such fans not only aid in ventilation, but they also assist in keeping off mosquitoes.

**Instruction of men.**—All officers and men taking part in
the expedition should be carefully instructed in the causation and pathology of malarial fevers, as well as of other tropical diseases. The important part played by insects should be pointed out, and special emphasis should be laid on the fact that the causation of these diseases is not of an esoteric nature but the mere commonplace result of the bite of a commonplace insect. The miasmatical theory dies hard, and it is not easy to get the lay intellect to realize that disease is not caused by some mysterious power of induction possessed by some intangible emanation. The period occupied or spent on board ship can profitably be utilized for this instruction.

We now come to the period of active operations, and the first point to be considered is the base of operations.

Amongst the instructions to Sir Garnet Wolseley in 1873 it was laid down that if the use of European troops became imperative everything should be prepared in anticipation, and not a man be landed before the moment for advance into the interior arrived. The accommodation for troops at the base need not therefore be large, and may be limited to that for the details left there on duty, with a small margin.

Measures directed against the breeding-grounds of the mosquito, which should have been, as already stated, drawn up by the special medical officer entrusted with the preliminary survey of the base, must be carried out as in cantonments in time of peace. A specially selected medical officer should be placed in charge of these operations with executive and disciplinary powers, a step that has been proved to be so effective by the officers of the United States Army in Cuba and elsewhere. This officer should be provided with an ample supply of native labour, and such number of European subordinates, preferably N.C.O.'s of the Royal Army Medical Corps, as the size of the locality demands. Any parsimony in this direction may have serious results. Presumably, the base will not be in the immediate vicinity of a native village. Nothing but the most urgent strategical necessity can justify such a
The Base

Selection. In addition, all native establishments must be encamped or huts at a distance from the European lines. Their defence and discipline must be ensured by appropriately situated outposts, electric lights and barbed wire fencing being used to assist in these and prevent desertion. The guns of the fleet can, of course, assist in defence. It may be necessary to erect a base hospital, but patients should be retained there only as long as to permit of rest prior to evacuation.

Two hospital ships should be used on any tropical expedition. Of these one would always be available for the reception of sick coming from the front, whilst the other was carrying its passengers to the nearest healthy port or island.

It is essential to insist that there is no difference between the conditions at the base, and the conditions of any cantonment during ordinary peace time. Everything that is possible in the latter case is possible in the former, and should be carried out with the same thoroughness and the same careful organisation. The subject of prevention of malaria in cantonments is treated of elsewhere, so more need not be said here.

The important point, and this cannot be too often repeated, is that undivided responsibility should be given to one man, and that authority of equal extent should go hand in hand with the responsibility. So only can success be hoped for in the war against malaria.

Leaving the base of operations, the force now proceeds on its mission. Detachments will no doubt be made from time to time of small bodies to hold fortified posts on the Lines of Communication. These detachments may have to remain stationary for the greater part of the campaign, and in their case regular anti-mosquito measures must be undertaken, as far as possible on the same lines as at the base, or in cantonments in peace time. The proximity of a native village will necessarily be avoided as far as possible. Where the tactical situation necessitates such proximity, the village, if deserted, must be destroyed by fire directly the permanent occupation
of the post is decided on. If still inhabited some trouble may
arise, but it would be preferable to forego some minor tactical
advantage than to run the great risk of disease that such a
situation entails. If the tactical considerations are paramount,
then the inhabitants should be, if possible, evicted. Such shelters
being built for them at a little distance, and any necessary
compensation paid. The site could then be as already recom-
manded, cleansed by fire. Since it may be accepted that the
mosquitos already existent in the neighbourhood of the post
are infected, it would be advisable to adopt the method origi-
p. 72) of constructing mosquito-traps from small boxes, lined inside
with some dark material.

Dr Rii. Principal Medical Officer of Conakry, utilised a
similar method in Dahomey in 1905 (Arch. for Schiff~
and Hygiene, Bd. xiii. 1905, p. 643). He noticed there
that the adult insects were in the habit of sheltering them-
selves during the hot hours of the day in the burrows of the
land crab, and in holes between the roots of mangroves. He
accordingly caused small holes to be dug in the ground about
16 inches deep, at a somewhat acute angle to the surface. These
holes were so situated as to be protected from direct sun-
light, and were, if properly placed, invariably crowded with
mosquitos. These insects remained in their shelters until
4 P.M. as a rule, and accordingly between 2 and 3 P.M. on
each day the holes were burnt out by means of a small torch,
consisting of a stick about 3 feet long, at the end of which a
piece of rag or tow, soaked in petroleum, was fixed. Such a
torch will burn for about ten minutes, and one will suffice to
burn out fifteen to eighteen holes if in close proximity to
each other. A well-trained native can attend in this manner
to one hundred mosquito-traps in a day. The cost is trifling;
3 litres of oil are sufficient for five hundred torches. Fresh
holes must be dug once a fortnight, as the old ones become
saturated with oil. As far as possible all permanent posts
should be provided with mosquito-proof hats, and in their absence mosquito-netting should be supplied to the men.

Night duties should be reduced to a minimum, and sentries relieved every hour, or even oftener. The very fullest use should be made of mechanical appliances, barred wire entanglements, searchlights, etc., with a view to lowering the strain on the sentries. Hot coffee, cocoa, or tea should be freely available for all men exposed to the night air. On no account should fatigue, which can be performed by natives, and for which natives are available, be carried out by Europeans. The question of the prophylactic use of quinine will be discussed later.

With regard to moving bodies of troops, which do not occupy any one camp for more than forty-eight to seventy-two hours, it is obvious that measures directed against the breeding-grounds of the horse can be of no avail. Before any such measures can have effect the force will already be many marches away. The defence therefore limits itself to the protection of the men from the adult mosquitoes, and by preventing the access of the latter to the exposed surfaces of the body, or, as a last resort, to rendering individuals immune to the plasmodium by the use of quinine.

The former can be achieved by the use of mosquito-veils and gauntlet gloves by men on night duty, and, doubtless, by the use of mosquito-netting when asleep. Unless a man is provided with some sort of framework wherein to support the curtain, it is doubtful in how far this precaution is of use. Obviously a complete set of poles for mosquito-curtains cannot be carried by each man. The issue of a couple of yards of netting to each member of the force is at the same time a precaution that may with advantage be adopted. The use of essential oils for the purpose of anointing the exposed surfaces of the body has much to recommend it. It causes less discomfort than that entailed by the obstruction to respiration when veils are worn. There is at the same time less hindrance
THE PREVENTION OF MALARIA IN WAR

Kerosene or paraffin oil, everywhere procurable in the tropics, serve this purpose as efficiently as any of the more elegant aromatic oils.

Last of all we come to the prophylactic use of quinine. When it is impossible to control the breeding of mosquitoes, or to protect oneself from the bites of the adult mosquito, then it is necessary to have recourse to the prophylactic administration of quinine. But it must be premised that such a system of prevention of malaria is a confession of failure. Success may be difficult, or even impossible, under the many vicissitudes of campaigning in tropical jungles when troops are constantly on the move. Success may be difficult, but it should not be impossible, under conditions such as prevail at a properly selected and administered base of operations. The prophylactic administration of quinine should not therefore be looked upon as anything but a last resort, or a merely temporary expedient in the case of troops living under settled or comparatively settled conditions. The prevention of disease by the administration of drugs is as unscientific as the treatment of disease by relief of symptoms only. Both courses may, under certain conditions, be imposed on us by the force of circumstance, but neither should be deliberately chosen as the chief method of defence, either in sanitation or therapeutics. The administration of quinine has this great drawback, that each individual has to be protected separately. The total mass of disease in the country is in no way affected. Every newcomer is still exposed to the risk of infection, just as much as his predecessors, and each such person must be protected. On any scientific system of sanitation the disease should be attacked, not after it has infected the patient, but before. Measures directed to the latter end protect the individual, not the community, whilst true sanitation aims at protecting the individual as an item merely in the community. If quinine
is administered, I lean personally to the German method of giving two large doses on two consecutive days, 10 to 15 grains, according to the idiosyncrasy of the individual. As a matter of practical administration this should be done once a week, on Mondays and Tuesdays, or any other days, but the same days of the week should be adhered to throughout. Thus, the dose is less likely to be omitted in such a case.
61. The Prevention of Malaria among Troops under Peace Conditions. — The vast importance of malarial fever can be appreciated by a glance at the following table, from which it will be seen that out of a total strength of European troops serving at home and abroad of 215,467 there are admitted to hospital each year 19,092 patients suffering from this affection.

The average constantly sick reaches the large total of 0.23%, which means that a number equal to the ordinary strength of a regiment is always hors de combat owing to this disease.

EUROPEAN TROOPS AT HOME AND ABROAD.
AVERAGE STRENGTH, 215,467.

<table>
<thead>
<tr>
<th>Year</th>
<th>Absentee</th>
<th>Deaths</th>
<th>Injuries</th>
<th>Hospitalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>1908</td>
<td>19,092</td>
<td>47</td>
<td>187</td>
<td>6,093</td>
</tr>
<tr>
<td>1906</td>
<td>17,965</td>
<td>33</td>
<td>197</td>
<td>5,700</td>
</tr>
<tr>
<td>1909-1907</td>
<td>54,934</td>
<td>913</td>
<td>270</td>
<td>7,747</td>
</tr>
</tbody>
</table>

The next table shows the incidence in some of the countries where malaria is most rife, and a comparison is here given of the effects of the disease during 1908 and the five previous years.

600
During 1908 malaria gave the largest gross number of admissions and therefore the highest admission rate per 1,000 of any disease on the nomenclature. This fact alone must point out the transcendent importance to the military sanitation of finding some means of lessening the disease and saving the enormous waste entailed by the loss of service of our soldiers and sacrifice of public money through inefficiency.

On looking at the table it will be seen that Western Africa heads the list under nearly every column of ratios per 1,000. The West Coast has always held a bad record for malaria, and this disease can be said to cause from 50% to 60% of the total admissions, invaliding and average constantly sick for all diseases at the stations in this command. The West Indian troops suffer almost as severely as the Europeans, but the West African regiments are much less susceptible.

The country which costs us most dearly is India, where we see how terribly heavy the toll of sickness caused by malarial fever is. The figure for 1907 was a great improvement on that for the ten years previous, but, unfortunately, 1908 was a wet year, fever was prevalent amongst the native population, and, in consequence, the figure again rose, in spite of all efforts to diminish it.

<table>
<thead>
<tr>
<th>Year</th>
<th>Admissions</th>
<th>Deaths</th>
<th>Sick</th>
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</thead>
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<tr>
<td>1906</td>
<td>16,275</td>
<td>72</td>
<td>650</td>
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<tr>
<td>1907</td>
<td>18,441</td>
<td>73</td>
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<td>1908</td>
<td>15,357</td>
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<td>445</td>
</tr>
<tr>
<td>1909</td>
<td>17,037</td>
<td>35</td>
<td>244</td>
</tr>
<tr>
<td>1910</td>
<td>13,116</td>
<td>22</td>
<td>199</td>
</tr>
<tr>
<td>1911</td>
<td>11,694</td>
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<td>198</td>
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<td>1912</td>
<td>7,647</td>
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<tr>
<td>1913</td>
<td>10,992</td>
<td>35</td>
<td>279</td>
</tr>
<tr>
<td>1914</td>
<td>12,112</td>
<td>11</td>
<td>279</td>
</tr>
<tr>
<td>1915</td>
<td>16,357</td>
<td>24</td>
<td>64</td>
</tr>
</tbody>
</table>
It should be noted that since 1905, a large number of men, averaging from 4,000 to 5,000 each year, are treated in barracks.

Amongst the native army of India malaria is also very prevalent. During the last ten years the average strength of these troops has been 15,523, of whom 1,404 have been each year admitted to hospital, to say nothing of those treated in barracks and not coming on the returns.

Having thus briefly outlined the incidence of malaria amongst the various stations of British troops, there is now to be considered what means of prevention can best be employed to counteract such serious losses. In the first place, it must be presumed when formulating any means of prevention, that readers are believers in the part played by the mosquito in the transmission, spread and maintenance of the malarial parasite, and have absolute faith in the formula of "No mosquito, no malaria." It would appear mere waste of words to make such a statement at the present day, were it not that experience has shown how even now there are people, including members of the medical profession, who still retain doubts of the mosquito being the sole carrier of the malarial parasite. All recommendations here made will be based entirely on the proved facts of malarial transmission by the aid of certain varieties of Anophelines.

In formulating the measures of prevention most applicable to troops, it must always be remembered that the soldier cannot be thought of in his position as a unit only; there also has to be taken into consideration the inhabitant of the country in which the soldier is residing. It may be stated, as a general axiom, that if the native suffers from a certain disease, it will almost necessarily follow that, unless extraordinary precautions are taken, the soldier will inevitably suffer from the like complaint. The soldier is largely dependent for his health on that of the community around him. Therefore it comes to this in many cases, that to check malaria amongst the troops it will be necessary at the same
time to lessen it amongst the surrounding inhabitants. Thus the question can be seen to be a much wider one than would at first appear.

Preventive measures may be divided into —

1. General measures of prevention.
2. Personal measures of prevention.

1. The general measures of prevention are such as will be undertaken by the State, Local Government, or Community at large. As a rule they involve a considerable expenditure of capital, as well as a large amount of thought, trouble and probable legislation by those in power. For these reasons obvious means of cutting short malarial incidence have been on more than one occasion allowed to lapse, or only very inadequately provided for by Local Government officials. Failure must necessarily follow; and though the authorities may endeavour to make a scapegoat of the means recommended, the blame lies entirely at their own door.

In other instances financial considerations alone must block the way to improvement; and in certain of our colonies it is a question for serious debate whether the necessary funds should not be provided temporarily by the Imperial Exchequer. It is heart-breaking to look on the results of malarial havoc, knowing at the same time that this could be controlled, were power and money employed to the best advantage; and yet neither can be obtained.

These general measures can be dealt with but briefly in this section, but reference must be made to them as affecting the population surrounding the troops, on whose health the latter are so largely dependent.

At the present time there are two schools of opinion. One relies mainly on the destruction of the larval mosquito; the other, believing that such a desideratum is without the range of possibility, affirms that quinine dosage forms the mainstay of prevention.

The first school, relying chiefly on larval destruction, looks
upon quinine as a valuable aid certainly, but not to be placed
upon the same footing as the destruction of the primary agent,
except in certain cases where larval destruction is almost hope-
less. The second school base their preventive measures primarily
on quinine dosage, and hold that if the malarial parasite is
prevented from remaining in the human blood-stream by the
administration of quinine, then it is impossible for the mosqui-
to become infected.

In every country where malaria is present there is some
diversity of opinion as to which of these methods chief reliance
should be placed. This matter will be dealt with fully in
other sections, so that no further reference will be made to
it here, save to mention, as a general statement, that in the
majority of our possessions larval destruction is the one of
primary importance and trial.

A. The General Measures may therefore be cited as
follows:—

1. Larval destruction.

2. Segregation of the soldier.


1. Larval destruction, under this heading, means the
elimination of all spots where the Anopheles may find a home
or a suitable breeding-place, from which it can reach barracks,
cantonments or other sites where troops may be quartered.
The question at once arises: What is the probable or possible
flight of one of these insects? A reply of fact and not of
theory it is impossible to furnish. Some years ago many
authorities would have judged the probable limit of flight at
a few hundred yards but facts have arisen since then, showing
that mosquitoes under favourable climatic conditions can and
will travel several thousands of yards from their breeding-place
to their feeding-ground. To lay down a precise distance of
safety is quite impossible, but a reasonable limit within which
no breeding-spot should be allowed around barracks, may be
quoted at 2,000 yards or thereabouts. Now many of our barracks abroad are built on small plots of ground belonging to the War Department, but the land closely adjoining may be quite without their jurisdiction; the consequence being that the Military Authorities have no power to enforce the abatement of evils existing on the ground of neighbouring tenants.

At the present day no barracks should be built in the tropics or sub-tropics on ground which does not include the control of an area of 2,000 yards radius from it as the centre of a circle. Unless this plan is carried out the troops occupying the barracks must of necessity be exposed to all dangers arising from a neglected condition of the surrounding area, as well as the risk of being infected with other diseases from which the inhabitants living on this ground may be suffering.

Many examples of barracks situated in this faulty position might be quoted from our Colonial garrisons.

When the State or War Department owns or controls the land around barracks, it is incumbent upon them to place this ground in such a condition that it shall not act as a breeding-spot for mosquitoes.

If such a land is not their property, and is forming a favourable source of origin for Anophelines, it is essential that the ground should be purchased, in order to gain complete control over it. The purchase may involve great expense, but this would probably soon be covered by the saving effected in the improved sick-rate of the troops.

(2) Segregation of the soldiers.—This has been referred to under the previous heading. It may be stated fairly conclusively that the wider the separation of the soldier from the native inhabitants the better will be his health. The barracks that have been carelessly placed in the midst of native towns, or that have become encroached upon and surrounded by native houses, will show a far heavier incidence of disease than barracks standing in isolated positions. The reservoir of the malarial parasite is to be found chiefly in the children of the
native inhabitants. An infected village with a high spleen rate amongst its children will contaminate any camp or settlement within a wide distance of its site. Such a condition of things exists in numbers of our garrisons abroad.

Take the case of so many of our Indian stations. The barracks may have originally been placed at a reasonable distance from the native town, but a bazaar has been allowed to grow up alongside them for the use of servants and others serving or trading with the troops. Many of these sudden Bazaars contain several thousands of inhabitants. Malaria or any other disease from which they may suffer must inevitably spread to the troops.

Again, within the Indian cantonment, until quite recently the native was allowed to grow any sort of crops, and to do practically whatever he wished with the ground rented. The consequence was, and still is, in some places, that rice fields existed within quite a short distance of barracks, to say nothing of other crops requiring an abundance of moisture, which so generally means neglected ditches and the formation of small marshes. The outcry against the continuance of such a state of things has often been raised, but is invariably met by the answer that if such crops are done away with, the cantonment funds would disappear and financial ruin ensue. It is the duty of the State to insist on an abatement of such dangers; and if in any case its continuance cannot be stopped, then the troops should be moved and the station evacuated. Until the State can appreciate the enormous losses involved by the sickness of our soldiers from malaria and its sequelae, it is almost hopeless to expect works to be taken in hand, which must appear to the authorities to involve a large expenditure of capital without any evident financial return.

3) General quinine treatment.—By this is meant quinine treatment of the general population of the country in districts around the location of troops. This lies outside the measures to be undertaken by the Military Authority, who would only
be in a position to advise and not insist on such a campaign of defense. It would mean action on the lines of the Italian school, and will be fully dealt with in another section. The military forces would benefit very greatly, as the chief source of their contamination, namely, the native children, would be brought under treatment, and their capability of spreading the parasite by acting as reservoirs materially lessened.

B. Personal Measures of prevention must now be considered. These are such as can be carried out by units themselves and will involve no great initial expense, as is so often the case with the general measures.

The various means employed may be enumerated as follows:

1. The attack on Anopheline larvae in their breeding spots.
2. The defence against the adult Anopheline.
3. The segregation of malarial patients, and their protection from the Anopheline mosquito.
4. Segregation from the native.
5. The administration of quinine.

It is one of the first duties of an officer commanding a barrack or cantonment to see that the same is kept in a clean and sanitary condition. It must also be the duty of this officer to see that the place under his control in a malarious country is in such a state that mosquitoes will be unable to find any breeding spots on its area. If he does not himself understand or appreciate the hygienic importance of this order, he must be compelled to do so by a higher authority, and be made to accept the advice of experts who have made a special study of the subject. The attack on mosquito larvae can best be carried out by the formation of "mosquito brigades," or "working gangs," consisting of men especially trained to such work. These men may be either soldiers or natives of the country. It
MOSQUITO REDUCTION

It is not considered that the former are suitable for these duties. Soldiers are wont to despise such employment, and think it beneath their dignity to carry it out. In addition, there is always the likelihood of their being continually changed and assigned for other duties, just at a time perhaps when their services are most urgently required.

It must also be borne in mind that the heaviest work will fall just at the most trying season of the year, when the weather is intensely hot and perhaps saturated with moisture in a tropical country. Soldiers should certainly not be employed to perform this work.

It remains, then, to rely on the native. It has been found in practice that, if the proper class of native is selected, he is capable of being trained very efficiently to the work, but of course he will always need the supervision of Europeans.

The number of these men required will vary in accordance with the size and conditions of the barracks, cantonment or Air Department ground. Experience has shown that it is better to divide up the men into separate units or working gangs, rather than have a number of men engaged indiscriminately. A convenient working gang would consist of a head man with two or three underlings. The head men should be selected for their special aptitude in the work and should receive more instruction than their underlings, in order that they in their turn may be able to impart the information received. All the men employed must be given a general insight into the causation of malaria and be taught the life history of the mosquito. They must know the different species, both of the larvae and adults, together with their habits. They must also receive a course of instruction in the best means of dealing with casual water, in ditching and rough draining.

These men should be under the direct control of the medical or other officer appointed in charge of malarial work, and he will be responsible for their instruction.

Different ways of working the gangs can be arranged as best suits the individual place. For instance, the station may be...
divided up into six different areas, and a gang made responsible for each; or gangs can be employed on one of these areas for a day in each week. Again a gang may be appointed to each regiment or unit, and a man, preferably a N.C.O., made responsible for its working. The general duties of these gangs will be shortly as follows:—The exploring and examining of all ground around the barracks or cantonment; the collection of all tins, pots, pans, or other rubbish capable of holding water; the cutting and removal of all water vegetation, brushwood and scrub; the clearing and grading of ditches, the filling up of holes and hollows, the draining away of casual water and small marshes; the examination of water-tanks, water-buts, wells and cess-pools; the search for plants and holes in trees retaining water; the treating with paraffin-oil, tar or other larvicidal of all water that cannot be disposed of or properly protected.

It is advisable that attention should be paid, not only to the Anopheline larvae, but also to those of Culex and Stegomyia, as the destruction of the two latter, which are usually the more domestic species and therefore more in evidence as nuisances, will show the inhabitants of the station that something is being done. Besides, in many places, these mosquitoes are a veritable pest, the Stegomyia by day and the Culex by night, and their destruction is worth some outlay, if only to obtain increased comfort.

When dealing with these larvicidal operations, the question of the station or cantonment irrigation is certain to arise. Where a canal supply is in force, as in many parts of India, it is well-nigh impossible to act efficiently on the Anopheline larvae, unless such irrigation is stopped. The main canal, as it passes through the cantonment, is broken up into numberless small channels for the distribution of the water. These generally become little better than rough and neglected gutters, overgrown with vegetation, and allowing the water to stagnate. Small patches of marsh or water-logged soil are often formed.
by the side of these channels from leaking or overflowing of their banks. There will form ideal breeding spots for most varieties of the Anophelines. On the other hand, it has to be recognised that if irrigation is cut off, the cantonnement will be turned into a desert. Irrigation from wells is by no means objectionable. The supply of water is limited by the labour necessary to raise it from the well, and therefore only a sufficient quantity to irrigate the crops themselves is drawn. Water seldom stands wasting in channels or sides, so that the Anopheles have little opportunity of finding any breeding pools.

A medical officer should be detailed for each station or cantonnement to look after all malaria work, and he should be placed in charge of all the working gangs to direct and supervise their operations.

At the headquarters of each district or province a medical officer possessing special knowledge on the subject of malaria should be appointed. It should be his duty to travel from place to place, to supervise the work being carried on, and to advise as to future procedures. All reports on malaria from the out-stations should be submitted to him, in order that he may collect the various details, and be in a position to form a reliable opinion on the efficiency or otherwise of the different measures of prevention.

(3). The defence against the adult Anopheles.—The means at disposal are mosquito-proof houses and mosquito-curtains.

In Europe, or even in a sub-tropical climate it is easy to lay down rules and carry them out as regards the use of the above means. The matter resolves itself into one only of expense for their provision. In the tropics the situation is far different. Here the most prominent question is: Will the troops or others make use of such means if they be provided? or even it may be asked: Can they be allowed to do so? To those who have experienced hot weather on the plains of India, this point is one that is only too vividly appreciated. To
expect any one to remain under a mosquito-net during the day or night-time of the hot weather, or even to remain in a room, the windows of which are blocked by wire-gauze netting, is scarcely reasonable. Existence would be unbearable, and in all probability sacrificed to an attack of heat apoplexy. Unfortunately the use of mosquito-curtain and punka is incompatitable, at least for the soldier. Mosquito-proof rooms and powerful electric punkas or fans might be borne. In many parts of India, for five or even six months of the year, punkas are a necessity of existence, and therefore curtains cannot be made use of. It is impossible to lay down definite rules in regard to this question. In each district or station the various points will have to be taken into consideration in a common-sense manner, and corresponding recommendations made. Mosquito-curtains should undoubtedly be provided for all soldiers in a malarious locality, and they should be made to use them if the climatic conditions permit. The form of curtain varies. The bell pattern is the cheaper, more easily managed and hung, but does not allow the same air-space within it. This appears a minor point in the subtropics, but is soon appreciated under tropical conditions. The old pattern square shape is now again being used on this account, but the obstruction to ventilation and air movement becomes very great when each bed in a barrack room is fitted with these curtains. Men must always be instructed in the best method of hanging them, otherwise they are worse than none at all, and act simply as traps. In many cases it has been found that although curtains are provided, the men are not in the habit of using them when on guard or attached duty, and consequently become infected. The provision of wire-gauze for all doors, windows and ventilators in a barrack-room is one of theoretical excellence, but one of great practical difficulty. The expense, both initial and recurring, is of some magnitude, and constant watch must be kept on the proper fitting and closing of the openings; otherwise the soldier is
sure to remove what he will consider are useless obstructions to the breeze. In certain isolated and dangerous positions, where a small number of men are on duty, the employment of this method is undoubtedly a sound one, but as a general preventive measure it has not been taken up for our garrisons. As regards the destruction of the adult mosquitoes, but little can be done. The majority of the Amphelines are night feeders, and as a general rule will have a rest before daylight. There are some variations, however, which will remain a certain time after entomopod, and can be found in the dark corners of rooms. Various means have been devised for killing off these insects by fumigation, such as the burning of sulphur, benzin or other chemicals. These methods are of but little use in the tropics, where it is most difficult to render a room in any way fume-tight. The safest procedure consists of the regular sweeping out of all dark corners, removal of unnecessary hangings, and thorough cleanliness. Many so-called specifics have been brought forward, purporting to ward off the attacks of mosquitoes when smeared on the skin, such as soaps, ointments, oils, etc. Some of these are excellent, whilst their virtue lasts, but the latter is very evanescent, and few of them are found to be efficient for more than about half an hour.

3. The segregation of malarial patients and their protection from Amphelines.—This is a most important matter and one that has been much neglected up till very recently. It was customary to place patients suffering from malaria in any ward with other patients not yet infected, no provision being made or even thought of to prevent infection being carried from one to the other. In consequence, many men who were in hospital for some trivial complaint became infected with the parasite during their detention. At the present day it is understood that a patient suffering from malaria is a danger to his non-infected neighbour, and he should, therefore,
be placed in a separate ward, and provided with curtains, or if these cannot be borne, then the ward must be rendered impervious to the entrance of the mosquito. In any station where malaria is prevalent, these precautions are essential. A ward containing malarial patients unprotected from the attacks of the Anopheline carrier, is a great potential danger to the surrounding community, and should not for one moment be tolerated.

(4). Segregation from the native.—The importance of this has been referred to previously under general measures of prevention, when insistence was laid on the advantages to be derived in separating soldiers entirely from the native houses and population around. It must not be forgotten that the soldier may still easily contract the disease by visiting places or towns, where malaria is rife amongst the inhabitants, and it is very necessary to do everything in one's power to prevent such excursions, more especially after dark.

When troops attend camps of exercise or are on the march through a malarious country, the encampments should always be placed as far as possible from any native village or from any spots where infected mosquitoes are likely to be prevalent. The same advice can be given as regards shooting-trips, on which the officers often, and the soldier occasionally, proceed. Native guides will always try to induce a party to pitch their encampment in close proximity to a village or water of some kind, for obvious reasons of supply. This should not be allowed, but the very opposite plan adopted. The use of nets for soldiers when on the march is almost impossible, crowded as they are together in small tents, but for the officer it is quite a simple matter to carry a small bell-shaped net and sling it up from the tent wall or branch of a tree at night. On shooting-trips during the malarious season a net should invariably be carried. It is very light and easily packed, if the supporting ring is hinged to fold over.

(5). The administration of quinine.—This drug must be
employed for the soldier as for the general population, namely to (a) cut short the actual attack, (b) prevent relapses, (c) prevent the infected acting as reservoirs and potential spreaders of the parasite; (d) act as a prophylactic agent.

(a) The various methods of administering quinine as a curative agent will be dealt with in other sections, so that further reference to this point will not be made. The treatment of the soldier differs in no way from that of a man in civil life, and army medical officers have now a free choice of any method which they may select.

(b) It may be taken for granted that, if a patient has been infected with the malarial parasite and suffered from an attack of fever thereby, it will require a period of probably three, certainly two months, continuous and rigid treatment, before the parasite is rendered more or less inactive. To say that it is destroyed is not possible, however energetic the treatment may be.

The failures of quinine to prevent so-called relapses are not generally failures in the true sense, as the reemergence of the attacks is in the large majority of such cases due to a reinfection. This is the reason why it is so extremely difficult to cure a patient when he still continues to reside in a malarious locality. Within the last few years the importance of the after-treatment of all soldiers affected with malaria has been appreciated by army medical officers, and nowadays every care is taken to carry on continuous treatment over a period of several months and to record results.

It may be presumed that the blood of every suspicious case of fever now admitted to a military hospital will be examined for the malarial parasite.
and that the diagnosis of malaria will never be made unless a positive result is found. When a malarial patient is discharged from hospital, some such scheme as the following may be employed.

The man is given a paper, telling him on what days he must attend for doses of quinine. A duplicate of this order is kept by one of the hospital staff, whose duty it is to give the paper, note the dates of attendances, and report any failure to do so.

The reason why continued treatment should always be briefly and reasonably explained to the patient, in order that he may grasp the importance of taking quinine regularly, not only for his own sake but in the interest of his comrades. The treatment must be enforced; but as a general rule there is not much difficulty in making a soldier who has once had an attack of malaria realize that it will be to his benefit to continue treatment. Every facility must be given to him for obtaining the necessary doses.

There is some variance of opinion as to the best method of giving the drug. For soldiers the most suitable plan is perhaps the administration of 10 or 15 grains of the sulphate or its equivalent on two successive days every week or on three successive days every ten days over a period of three months. During this time the blood should occasionally be examined for the presence of parasites and the treatment modified if necessary.

To prevent the infected acting as reservoirs of the parasite: Treatment for this object is in reality bound up with that mentioned for the prevention of relapses. If the latter do not occur, it is improbable that many or in fact any gametes are
circulating in the patient's blood. Similar lines of giving quinine can therefore be recommended.

As a prophylactic agent: On the use of quinine for this object there is a considerable diversity of opinion, and the latest military reports are not by any means favourable to any definite conclusions of the benefit ensuing from its administration. (A.M.I. Report, 1908, India.)

However, there has been undoubted evidence of beneficial action exerted by its use, and it is therefore the duty of the medical officer in charge of troops to administer the drug whenever malarial conditions are widely prevalent. It must always be remembered that positive results, as the outcome of quinine in prophylactic dosage, are most difficult to estimate. Negative results are declared only too vividly, and a few of the latter as facts far outweigh any estimations of the former as theories. In considering the results, it should be also be kept in mind that a large proportion of the cases admitted to hospital, probably more than 50% in some stations, are relapses, and that the administration of quinine may greatly lessen the number of such relapses, quite apart from any action in preventing fresh infections.

The difficulties encountered in carrying out an efficient prophylactic issue are very great. The soldier is extremely suspicious, when forced by order to undergo such a change, and will often do everything in his power to evade it. Considerable tact must always be employed in order to win over his confidence. In any case the drug must be taken by order, and in the presence of the medical officer or other reliable person. An issue to volunteers only soon resolves itself into a farce.

The drug may be given in solution, or in the
form of pills or tablets. Solution has the advantage that it is always at hand and easily made up, but the taste is of course extremely disagreeable to most people. Pills are convenient, but take some time to make, and do not keep well under conditions of heat or moisture. Tablets are really the most useful form, and given as a preventative only, they are unlikely to pass through the intestine unchanged. The uncoated form should be used. As regards this, there is a note in the A.M.I. Report, 1900, to the following effect. "As is usual the men disliked the quinine parade, and many adopted every means they could to avoid swallowing the dose; tablets of quinine were found unsuitable, since many men kept them in their mouths until the parade was dismissed, and then threw them away. Hence, quinine in solution was administered, and each man had to shout out his regimental number immediately afterwards to prove that the dose had been swallowed."

The above is one typical instance of resentment at compulsory treatment, and points out how extremely difficult it must be to rely entirely on the results of quinine prophylaxis under military conditions.

As regards the dose, there is some difference of opinion. A daily administration of 5 grains cannot be recommended for soldiers, owing to the trouble it involves in the parading, etc., of the men. In India during 1908, where in 53 out of 58 plains stations quinine was given as a prophylactic during the malarious season, in the majority of the cases 10 to 15 grains were used on two consecutive days in each week. This seems to be as good a method as can be recommended.

One most important point not yet referred to is the instruction of the soldier and others in the causation and spread of malaria.
All such instruction should be given in a way which will appeal to the imagination, and the language used should be couched in the most popular style. Short descriptions of lantern slides are the very best means of imparting elementary knowledge of this kind. Each medical officer appointed to a division or district as an expert on malaria should be provided with a set of lantern slides and suitable lantern, and give short demonstrations in each station throughout his district. A full but elementary understanding of the cause of malaria and the rôle of the mosquito in its spread, will explain to the soldier the reasons of many precautions which he may have failed to understand and thereby neglected.

It will be found that the men are ready enough to receive such instruction, and become greatly interested in the subject, provided that the facts are placed in a simple and straightforward manner before them.
The game was shifted to a district of deep pools, and formed in exact the carved
stream up and the P., 1868. 9
62. Notes on the Malaria-Bearing Anophelines. — This section ought to have been placed in Chapter III, but has been relegated to the Addenda for the following reasons. Many works on malaria and on mosquitoes give lists of the malaria-bearing Anophelines, but mostly without exact references to the literature in which the incriminating evidence was published. Hence early in 1910 I directed Mr. W. R. Drawz, our Malaria Bibliographer (Tropical Diseases’ Research Fund), to collect all the data which he could find; but the work could not be completed in time for the earlier chapters of this book; and he reports that even now, after several months’ close search, some references have probably been overlooked. I am also much indebted to Mr. R. Newstead and Dr. J. W. W. Stephens, of the Liverpool School of Tropical Medicine, for their valuable assistance.

So far as we can find, the following is a complete list of the Anophelines which have been mentioned in various books and papers as being capable of carrying malaria:


I am indebted to Professor Hyams and Purves, University of Liverpool, for advice regarding the Latin roots.
Anopheles aegypti, Theobald (1900).
Anopheles argyrolarsis, (Robin-Uesv.) (1901).
Anopheles albitarsis, (Walker 1859) (1859).
Anopheles annulipes, (Walker 1859) (1859).
Anopheles arabiensis, Patton (1905).
Anopheles barbirostris, (Vos) (1902).
Anopheles bicoloralis, (Loew) (1758).
Anopheles (dirhomo) biuncha, (Theobald 1903).
Anopheles biwanbo, (Fall.) (1905).
Anopheles bizzarrii, (Theobald 1903).
Anopheles b. moquini, (Theobald 1903).
Anopheles b. seymouthi, (Theobald 1903).
Anopheles b. grigorii, (Theobald 1903).
Anopheles b. electri, (Theobald 1903).
Anopheles (finet) b. nigriprous, (Giles) (1900).
Anopheles b. muscati, (Giles) (1900).
Anopheles b. mercator, (Giles) (1900).
Anopheles bicoloralis, (Loew) (1758).
Anopheles bigutulalis, (Loew) (1758).
Anopheles b. humeralis, (Loew) (1758).
Anopheles b. humeralis, (Loew) (1758).
Anopheles b. grigorii, (Theobald 1903).
Anopheles b. seymouthi, (Theobald 1903).
Anopheles b. moquini, (Theobald 1903).
Anopheles b. nigriprous, (Giles) (1900).
Anopheles b. electri, (Theobald 1903).
Anopheles b. nigriprous, (Loew) (1758).
Anopheles b. muscati, (Giles) (1900).
Anopheles b. muscati, (Loew) (1758).
Anopheles b. nigriprous, (Theobald 1903).

An. maculipennis, which is known to be...
NOTES ON THE MALARIA-BEARING ANOPHELES (34)

Anopheles gravitalis, Dobson (1930), vide
   Lutzomyia concolor, Lutz (1896).

Anopheles jarrahi, Lutz (non Theobald) (1901), vide
   Nyssorhynchus albipennis, Giles (1900).

Anopheles kowari, Theobald (1901), vide
   Nyssorhynchus kowari, Liston (non Theobald) (1907).

Anopheles kochi, Dobson (1904), vide
   Colte kochi, Liston (1902).

Anopheles kiangchui, Chalmers (1900), vide
   Nyssorhynchus kiangchui, Theobald (1905).

Anopheles koi, Giles (1903), vide
   Nyssorhynchus koi, Giles (1903).

Anopheles kot, Liston (1902), vide
   Nyssorhynchus kot, Liston (1902).

Anopheles kunisi, Skuse (1890), vide
   Nyssorhynchus kunisi, Liston (1901).

Anopheles kutho, Theobald (1903), vide
   Nyssorhynchus kutho, Theobald (1903).

Anopheles maculipennis, Giles (1903), vide
   Nyssorhynchus maculipennis, Theobald (1902).

Anopheles maculipennis, Mayr (1878).

Anopheles manueli, Laveran (1902).
   Anopheles manueli, Theobald (1901), vide
   Nyssorhynchus manueli, Lutz (1899).

Anopheles manueli, Skuse (1888), vide
   Nyssorhynchus manueli, W. D. Schrank (1853).

Anopheles mastai, Theobald, vide
   Nyssorhynchus mastai, Theobald (1899).

Anopheles flavescens, Theobald (1901), vide
   Colte flavescens, Theobald (1901).

Anopheles folli, Theobald, vide
   Nyssorhynchus folli, Theobald (1901).

Anopheles feae, Giles (1894), vide
   Nyssorhynchus f. f., Giles (1899).

Anopheles fuscus, Say (1831).

Anopheles fusconitens, Say (1831), vide
   Anopheles fusconitens, Schrank (1853).

Anopheles furvus, Giles (1894), vide
   Nyssorhynchus furvus, W. D. Schrank (1853).
Anopheles sinensis, Westwood (1823).

Myzomyia flavipes, (Wiedemann) (1820).

Anopheles stephensi, Liston, 1920.

Myzomyia stephensi, Liston, 1920.

1. Anopheles superpictus, Theobald, 1905.

Anopheles longicollis, Gotthilf (1905) (not Anophalus).

Anopheles theobaldi, Giles, 1906.

Myzomyia alexandrae, Theobald, 1905.

Anopheles trivittatus, Liston, 1907.

Anopheles tennesseensis, Thomas (1910).

Anopheles stephensi, Liston, 1920.

Anopheles tennesseensis, Thomas, 1910.

Anopheles theobaldi, Giles, 1906.

Myzomyia theobaldi, Liston, 1907.

Anopheles pungens, Liston, 1907.

Anopheles longicollis, Gotthilf (1905) (not Anophalus).

Anopheles superpictus, Theobald, 1905.

Anopheles superpictus, Theobald, 1905.

Anopheles superpictus, Theobald, 1905.

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Anopheles superpictus, Theobald, 1905.

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Anopheles superpictus, Theobald, 1905.

Anopheles superpictus, Theobald, 1905.

Anopheles superpictus, Theobald, 1905.
626. Notes on the Malaria-bearing Anophelines (3).

M. culicifacies, Giles (2924) (1892).
M. fasciatus, Theobald (1895), vide M. culicifacies, Giles (2924) (1892).

M. f. f., Liston (non Giles) (1893).

M. sierrae, Theobald (1903).

M. indica, Theobald (1903).
M. d. d., Theobald (1903).

M. milii, Theobald (1903).
M. stolzii, (1899).
M. stolzii, (Liston) (1901).
M. spinipes, (Van der Wulp).
M. spinipes, (Laveran) (1902).
M. spinipes, (Grassi) (1899).
M. spinipes, (Wiedemann) (1828).
M. spinipes, (Donitz) (1902).

M. spinipes, (Walker) (1850).
M. spinipes, (Giles) (1900).
M. spinipes, (Wallon) (1851).
M. spinipes, (Giles) (1900).
M. spinipes, (James-Theobald) (1903).

Theobald (V, 34, 1910) says that this is probably only mauijanus (Grassi) with yellowed legs.
ADEXINA

Nyssorhynchus maculipalpis, (Giles) (1901).  
Nyssorhynchus maculipalpis var. indica, Theobald (1902).  
Nyssorhynchus maculipalpis, (Giles) (1901).

Nyssorhynchus maclellani, (Theobald) (1900).

Nyssorhynchus staphilus, (Latham) (1901).

Nyssorhynchus theobaldi, James (Thobald) (1903).

Pyretophonus maculipalpis, Theobald (1902).

Pyretophorus viridis, (Loew) (1906).

Pyretophorus viridis var. melin, Theobald (1907).  
Pyretophorus viridis var. aureus, Theobald (1908).

Stethomyia minoa, Theobald.

(a) I now add some notes on the species regarding which we have succeeded in finding some incriminating evidence. That evidence is of three degrees of value: (a) experimental proof that certain individuals of a species are capable of developing all the stages of any or all the species of the human Plasmodia, or of causing infection in man, or of both; (b) proof that a species may contain some of the stages of the parasites (zygotes); and (c) apparent correlation between the numbers of a species and the local prevalence of malaria. Here (c) is not conclusive, because, though the zygotes may develop to a certain degree in an insect, it does not follow that they come to maturity; and (c) is not worth much because, as we showed in the case of Nyssorhynchus maculipalpis, a species may abound in a malarious locality, although the disease is really being spread by quite another one. Lastly, even (a) proves only that the newly concerned
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in the experiments is culpable, because, for instance, we failed in
infecting English A. maculipennis, which certainly carry in most other
places. The reader should also note that the breeding-waters selected
by larvae in some places need not necessarily be the same as those
selected by the same larvae elsewhere.

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Anopheles algeriensis.-Ed. and Et. Sergent state that they found
protospores in the salivary glands of the two individu~l.ls cxaalincd by
them l19 5].
They also state that a violent epidemic of walaria
0
occurred in the villages of Thiers in AlgerIa, where it .:was not
possible to finu any other Anopheline except this one, Occurs in
Algeria, and the S(:rgents say t1lat it haunts !es ,{J.'linfs sahN,ellnfs~
and the pbins of the littoral.
Am,/,!Ifks araNo/Jis.--Apparently incriminated by W'. S. Patton
[19 5]. Literature not availaLle. Pruto:il-l0rcs [ounli in it. V,5tribu0
tion: Arabia and Aden. See Stephens and Chri~tol)hers [190~

p. 15 6].
Anopheles {izfurrafus.- There are two species of Anophe1ines under
the name of cbyiger, A. l1w(u/ijrIlJlis Fabr. and A. /!ljuuatus Linn.
Both appear to have lJeen incriminaku l)y the Italians by cultiV<l.tlon of
the parasites in all their stages, anu also by inoculatiun of hralthy
persons (see section 17, cases 2, 3, 4); but it is not always clear wLicll
species is refl..ned to. \Ye gather that A, mamitj'(IlJl/s is the ODe
concerned in the experimental inoculations, and ;;cnerally in the cultivations.
But Hignami and llasti:.ll1e1li also incriminated bijuJ'ralttS by
cultivation, Grassi says l190I] that he found it much more difEcult
to work with lnfureatus than with macu/ipwnis, owing to the small size
of the former but found zygotes in thirteen out of sixteen insects, and
l
adds (page 121, German edition) that parasites were fuund in ltifurl.'atus
and marulipennis in the Maccarese district. Jansc6 also [19 0 4, H)Oj
and 19 ] gives experiments with A, dtl'lll:![er without stating \\hich
08
dal'(Ker he referred to; but we gatber that he was referring to ma, ulipmnis. Probably /Jiju1'Iydus can be safd)' claimed as a carrier.
It is generally distributtd ov~r Europe anu :t\ orth America, In
England it is certainly the commo,,~st of the three Anophelincs, the
other species being maculiP(llIlis, and n(::,rii'cs~ Grassi states that it
occurs in forests and breeds in s~nall coUection5 of fresh water ~uch as
wells and in rot holes in trees; that it occurs seldom in houses and
stables, and that when one is Litten in forests it is generally by this
species. It bites more quickly than A. clai,igtr, and in the daytime,


and enters habitations at night. Newstead says that it is the commonest Anopheline in the New Forest in England, where the larva occurs in large numbers in the shallow pools and in the cutlet receptacles. In the number of Carlile it is also abundant, meaning chiefly in shallow, terrestrial waters, sometimes in company with the larva of Culex.

Anophyia femorunnata.—The entire position of this species has not been definitely fixed. Incriminated by J. T. P. L. [1913], who follows a completely the development of the malignant parasites in it, but did not inoculate man with it. Occurs in the whole island of Formosa. Thobald apparently disregards two varieties, one of which is common in the north and the other in the north of Formosa.

Anophyia microstoma.—Incriminated by the Italians, see under A. microstoma also by A. Van de Vel and Van Redish [1910].

A. j. stebbingi (1901) by E. St. Blane [1912], Hauser [1927], and by Jarrett [1904, 1905, 1906], and others. The proof is at complete cultivation of the parasites, and also by inoculation of man by the furunculose and by furred. Common and widely distributed throughout Europe, including Russia and Norrland. It appears also to be generally distributed in the United States of America, and also to be common in many parts of Canada. It is chiefly a diurnal fly, found in houses, sheds, stables, and barns, etc. This helme also obtains a very large extent in Great Britain. The larva never occurs in open terrestrial waters in marsh lands, in forests, and hilly places. Thobald states that in Britain the food of both sexes is entirely vegetable. Thobald, on the other hand, says it is very probably—some to man in Italy.

A. pseudomosambica.—Incriminated by S. T. Darling [1912], who found cystos as four out of thirty-five insects fed on cases of the malignant parasites, and also protozoons in the glands of one insect. He thinks that it is only slightly concerned in the transmission of malignant fever in the Canal Zone. Occurs in Panama, Colombia, and New Mexico. Darling says that it is one of the two commonest species in the Canal Zone, and breeds in most terrestrial waters.

A. tarsimarulata.—Incriminated by S. T. Darling [1913], who found cystos in thirty out of five hundred. Occurs in Panama, Colombia, and South America. It is doubtful if this species is referable to the genus Anophyia.
NOTES ON THE MALARIA-BEARING ANOPHELINES [Sci.]

Cellia alblll11a11a.—Incriminated by S. T. Darling [1910] who found zygotes in thirty-six out of fifty insects and protoclasts and protosporcs in three. Occurs in Panama, Brazil, British Guiana and in the West Indies. Theobald (vol. III, p. 111) states that Dr St George Gray says that this Anopheline will bite at any time of the day or night; that the breeding-grounds are extremely varied, such as collections of water, especially full of reeds; and records also that he has found larvae in brackish water in a lagoon that lies off from the sea. He states, however, that he has never found the larvae in water barrels or similar receptacles in towns. Darling [1909, 1910] says that this is the most important malaria-bearing Anopheline in the Panama Canal Zone and breed in almost any terrestrial water. It carries both malignant and tertian malaria. Theobald, in his "Malaria of Jamaica," also mentions mere and large swamps and irrigation water, etc., as breeding-places.

Cellia (liferasa.—S. T. Darling [1910] says that a zygote was found in one individual at Panama. Occurs in South America, the West Indies, Panama, but appears not to be an important carrier. From the records we gather that this is a less common species than C. albivittata, to which it is very similar (possibly only a variety).

Cellia pha,offis.—Newstead, Dutton and Todd [1907-1908] say that "malaria parasites were seen to develop in this mosquito at Rome." The insect was common at Jamaica, and has been reduced simultaneously with malaria by operations since 1910 (section 51). Pressat [1905] considers it to be malaria-bearing, but gives no evidence. Occurs in East, West, Central and Northern Africa. It is recorded also from Palestine. Theobald (vol. I, 1901) says that this mosquito occurs during the month of April in Mashonaland and during January in Egypt. I found the larvae in small swamps of almost fresh water caused by seepage from the fresh-water canal at Ismailia, also in an ornamental fountain and in water-cress beds. Not seen in sewage ditches. Villcock say that it is a domestic mosquito, both in the larval and adult stages. The adults enter houses in order to obtain blood. In the open the females bite most viciously at sunset. The water in which the larvae live is not brackish. Larvae, in various stages of development, placed in water containing a pH, common salt, die in less than twenty-four hours, but in water containing 1/100 common salt they live from two to three days, but become sluggish in their movements and appear to feed very little or not at all.
ADDENDA

Myzomyia albigarum.—Incriminated by Stephens and Christophers [15th April 1902]. Experimentally it can carry quartan as far as the protosporae, and the other two species as far as the larvae. In nature frequently found to be infected in 80% at Mean Art, and 30% at Etern, near Madras. Widespread in India, where it is one of the principal carriers. Breeds in pools in sandy river beds, sluggish irrigation channels, ditches, muddy trickles, edges of streams, etc.

Myzomyia ferment.—Proved by Ross, Amert and Amert [1905] to carry quartan (one out of five insects) and mild tertian (one insect) in West Africa. Further confirmed by Daniels [1905, p. 44] for malignant. Stephens and Christophers [1905] found one specimen to be this Orthochelin in the Duars, in India, but Thorshildz wholly did not admit the identity. Also observed by Button and Todd, who report that malaria was seen to develop in it at Etern, 1899. Occurs in Central, Western and Southern Africa, India, and the Philippine Islands. Breeds in clear water in small springs and edges of streams and rivers. Daniels says it cannot thrive in stagnant waters, and that it may be found in marshes, but only where the water is kept fresh by springs during heavy rainfall. Stephens and Christophers say that it breeds in running water, such as sluggish irrigation channels, ditches, etc. It frequents houses and does not leave them in the daytime. It feeds preferably at night, especially in the early hours of the evening, but also at other times, even in daylight, when free and in captivity.

Myzomyia listonii.—Incriminated by Stephens and Christophers. In this species protosporae were found in the liver, but only in nature. Also by Kinoshita [1905], who says it can be infected from 50 to 80%, in Formosa. Occurs in India, Japan, Federated Malay States. Inhabits running water, swiftly flowing.
THE MALARIA-BEARING ANOPHELINES

streams, sluggish irrigation channels, ditches, muddy trickles and edges of rivers.

Myzomyia turkudii—Lutz (1903) says that he is convinced that this mosquito carries malaria, but gives no further evidence. Oswald commuter (section 47) suspects it. Occurs in Brazil, British Guiana. Lutz who paid considerable attention to the biocenosis of this mosquito, states that it is found widely distributed in various places along the chain of mountains in the region of São Paulo and Santos. It breeds in Bromeliaceae plants.

Myzomyia rosae.—I failed in infecting this species in Calcutta in 1898-1899. Stephens and Christophen (1900) obtained experimentally quartan and malignant zygotes in a few individuals. Never found them infected in nature. They add that sporozoites were found in nature by Captain James, but sporozoites never in nearly 1,000 dissected. Stephens and Christophen, 1902 obtained quartan and malignant zygotes in a few insects bred from larvae grown in salt water (3.5%), but not in those bred in fresh water. C. A. Bentely also failed to discover the parasites in 475 dissected. Occurs in India, Ceylon, Malay States, China, East Indies, Philippine Islands, and Java. Breeds in foul puddles near habitations, clean clear water puddles without much algae, and often turbid with suspended matter, boats and puddles near houses, shallow muddy river, rice fields and cultivation of all kinds. Theobald states that Mr E. E. Green (Tropikal Apiculture, vol. xxvii. p. 84, 1906) considers that it is a malaria carrier in parts of Ceylon. He found the larvae breeding in a brackish lake at Batticaloa, and also in the coconut estates, in the small water holes used for watering young plants, and in shelters sunk at the roots of plants. I have often thought that the comparative healthiness of India may be due to the fact that this species ousts more dangerous ones. Vogel's suggestion is interesting.

Myzomyia turkudii.—Incriminated by Stephens and Christophen (1901). Found to carry, experimentally, malignant tertian zygotes. Occurs in India, and found in large pools in quarries, story and shallow running waters.

Myzomyia turkudii.—Incriminated by Stephens and Christophen (1901). Found to carry, experimentally, malignant tertian zygotes. Occurs in India, and found in large pools in quarries, story and shallow running waters.

1 See also section 65 (b).
to have been found at Old Calder (4). Breeds in running waters with much weed and algae, swamps, and deep water with much aquatic vegetation.

*Anopheles albimanus.*—Takahashi (1919) proved that the parasites develop in all stages in the mosquito and that it causes intermission in a healthy man. They say that quinac pemoxe develop in some of these parasites; but he did not infect man with this species of parasites. Kilner (1901) bred various parasites in some of the species of mosquitoes, but quinac pemoxe only at low temperatures, and malignant parasites not at all. Occurs in dermatitis, Japan, China, Federated Malay States. Habits not described.

*Anopheles barbirostris.*—Incriminated by Makino (1917). Experiments not mentioned, but certainly a carrier. In Philippines and the Federated Malay States. Breeds principally on the flat courses, but not in running water. Abounds in thick jungle which it will not willingly leave, so that removal of jungle round plantations required malaria (section 57).

*Nyssorhynchus annulipes.*—Kilner (1919) developed malquart, only at high temperature without rippling, in three out of five mosquitoes. Occurs in South West Queensland, South Australia, New South Wales. Giles and Liston say it occurs in the Kimberley District. Breeds both in fresh and in salt water (1494, p. 164), and will live for a month on dates.

*Nyssorhynchus maculipalpis.*—Incriminated by Stephens and Christopher (1905) and Aitken (1915). Stephens and Christopher say that it occurred in Minn, Min in small numbers, and think that it is not an active agent. They were able to infect it experimentally for malignant tertian (zygotes), in the ripe yolk-of medium and thin small eggs. It developed also quinac up to syphylis. Occurs in India, Federated Malay States. Breeds in puddles and pools with much algae, common in streams beds, near trunks of trees and rocks and lakes with woody margins. Giles and Liston say that on a rule this species prefers open water and sunlight.

*Nyssorhynchus maculipalpis.*—Stephens and Christophers found parasites experimentally in this mosquito, which they called M. annulipes. Occurs in India, Mauritius, Macao, and in South America with it. Breeds in marshes on sea coast, and at 1400 feet above sea.

*Nyssorhynchus syriacus.*—Stephens and Christophers (1902)
NOTES ON THE MALARIA-BEARING ANOPHELINES [1927].

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developed zygotes of malignant tertian in it, experimentally. W. G. Linton [1909] at Bombay found 25% infected with malaria. C. A. Bentley, in the same city [1909], found zygotes in 30 and protospores in 8 out of 504 dissections. Occurs in many parts of India. Breeds not only in open, clean terrestrial waters, but in deep wells, iron cisterns, filter beds, garden tanks, and even small vessels (section 55).


Nyssorhynchus milbei. — Inkrininated by Malcolm Watson (section 53). Details of experiments not given, but the insect seems to be certainly a carrier in the hilly lands in the Federated Malay States. Also Dieache [1909]. Occurs in Federated Malay States, Kedah, Ceylon. Breeds in rapidly running streams, and cannot be reduced by open drainage. The larvae were found in the clear pools formed by a spring at a height of 4,700 feet in Kashmir (Theobald, vol. iii. p. 80).

Fyrophorus flavipes. — Rilliet states that this mosquito occurs exclusively in places where there is much malaria in the Saharian Ooses in Algeria. He had no opportunity of finding zygotes in the insects, but is sure that it is a carrier. Theobald (vol. iii. p. 27) says that protospores have been found in it. Occurs in Algeria, Tangieritis in Algeria, and southern parts in Sahara. Breeds in water containing a higher percentage of salt than normal sea water. Larvae are found in little isolated pools or ponds, which, under the influences of active solar radiation greatly increase in the percentage of salt, giving at the end of summer a percentage of 40 grams per litre. (Fisly and Yvermault, Bull. Soc. Patl. Exot., 1908, iii. iii. p. 172-175.)

Fyrophorus attenuata. — Incriminated by Ross, Annett, Austen [1907] to carry all three species in 27 out of 109 insects. Also by Stephens and Christopher [1909] and by E. Ross in Mauritius [1908]. Common and widely distributed over the African continent, Madagascar, Reunion and Mauritius, but not in many neighboring islands which are non-malarious. Breeds in stagnant terrestrial waters often without much weed. Appears to prefer the sea coast in Mauritius, but was found in marshes up to 1,700 feet, where, though scanty, it caused malaria. Breeds in pools in dried-up beds of hill streams,
and in weedy margins, etc. In Mauritius prefers verandas to inner rooms, and bites in the open, especially after 10 p.m. Takes shelter from wind, but wanders far on windless nights.

*Protophora mucronifera* (P.)—Introduced by Ed. Sayens (section 51), who says that the protophras have been found in it. Occurs in Algeria, especially in broken, hilly valleys.

*Protophora sapinata*.—Grassi seems to think that it is a malaria carrier (German translation, p. 176, [191]), but apparently goes no evidence. Also Signani and Rottelli think that it is a carrier. Occurs in the South of Italy, Spain, Greece, Algeria, and (?) Africa and India. "Cereus fimbriae" considered.

This concludes the Anophelines regarding which we have been able to find any reliable experiments, but other species are mentioned as being possible or certainly carriers, but without giving the evidence. That Oswald C. M. (section 48) says that *Chelyphora multivulcata* Theobald and *Theobaldiana canadensis* Grassi, and *Anopheles pseudomelanopus* Grassi, are undoubtedly carriers, as shown experimentally; C. Daniels, in a letter to me of the 15th June, says that *C. kodlii* is the constant in badly malarial schools in the Malay States, and is absent or scanty in other places. A. Groenow (section 46) Theobald says the only mosquito which he could find in badly malarial jungles. He adds that it was difficult to make any experiments with these two species, as they all live in confinement, and says: "The trouble with these, as with several other mosquitoes, is that whilst you cannot absolutely exclude them because there is no positive proof (experimentally), you cannot exclude them because there is no negative proof (experimentally), and the circumstantial possible evidence is strong." Insect families two species which he calls *pulverous* and *meditoxicous* as being carriers, but the mosquito itself did not to accept them as species. Obviously much more exact work requires to be done even on this point, which is so important for public prevention.

C. S. Banks (1907) states in a lengthy paper that he maintained plasmodia in *Myzomela heliara* Theobald, a Philippine Anopheline which breeds in swamps and graves and also in water, and that he introduced a healthy person — by the means— but certain points in his description suggest doubts as to the nature of the bodies which he considered to be malaria parasites.
64. Examples of Legislation. — Notes on legislation have already been made in section 40 (a) and 59 (1). The object of such legislation is to give the Health Department power (a) to enter private premises (including houses, yards, gardens, lands and estates) in order to search for mosquitoes, flies, rats and other annoying or dangerous vermin; (b) to destroy such vermin when found; and (c) to prevent the breeding of them. Another object is to compel owners or occupiers to take reasonable precautions against such breeding. But at the same time the rights and properties of the owners or occupiers have to be duly guarded.

Most civilised nations countries now possess Health Acts, more or less based upon precedent, and these contain clauses against "nuisances." But the word "nuisance" is not always defined so as to include the breeding of vermin. In such cases, then, it suffices merely to extend by act the definition of the word — if possible, to include all vermin as well as mosquitoes. It was my duty in Mauritius to consider the local Ordinances confounded for this purpose; and I drafted the following clauses, which were scrutinised and accepted by the Health Department and by the Procureur General, and then submitted to Government. (The first clause here given was meant to be inserted in the definition of "nuisance" contained in the Health Ordinance already in existence):

1. All collections of water, rubbish, refuse, excreta, or other fluid or solid substance, and all other conditions which permit, or facilitate, or are likely to permit or facilitate, the breeding or multiplication of animal or vegetable parasites of men or domestic animals, or of insects or other agents which are known to carry such parasites, or which may otherwise cause or facilitate the infection of men or domestic animals by such parasites.

2. It shall be lawful for any sanitary authority, or any person deputed by him in writing, to take immediate steps to destroy mosquito larvae on any premises where they may be found, and to take such action as may be necessary to render any pools or accumulations of water unfit to be breeding places for mosquitoes.

3. When such pools or accumulations of water lie on premises under the charge of a public body or corporation, they shall not be dealt with as above provided, unless due warning has been given in writing to such public body or corporation, and no action has, within reasonable delay not to be less than twenty-four hours, been taken by them. In such cases the expenditure incurred shall be borne by such public body or corporation.

4. Any owner or occupier who shall object to pools and collections of water on his premises being dealt with as above provided, shall within twenty-four hours submit his reasons to the sanitary authority,
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who, after enquiry, shall order such action to be taken as he shall consider necessary to meet the provisions of this Ordinance. Should the objections be sustained, the measures originally ordered shall be carried out at the expense of the said owner or occupier.

31. It shall not be lawful for any owner or occupier to allow mosquitoes to breed on his premises, or to allow the presence on such premises of any receptacle in which water is kept or may collect, under which circumstances are properly protected from access of mosquitoes, unless the water they may contain is treated in such a way as to prevent the breeding therein of mosquitoes, nor shall such owner or occupier allow on his premises any conditions which may, in any way, be conducive to the breeding of mosquitoes.

"Thus on all premises shall be at all times kept body lopped to the satisfaction of the sanitary authority by the owner or occupier, and no trees shall be allowed to grow within 20 feet from any dwelling-house. The sanitary authority may, in writing, direct the said owner or occupier to carry out the above provision within a reasonable time, but not more than forty-eight hours, and, in case of non-compliance, such trees shall be lopped or cut down at the expense of the said owner or occupier.

"It shall be lawful for the Director of the Health Department to make such regulations as may be necessary to carry out the provisions of this Ordinance.

"It shall be lawful for the Director of the Health Department, in any case when the owner or occupier of any premises is liable for the expense of any measures carried out on his premises, to allow such owner or occupier from the said expense, if, after enquiry, the Director is satisfied that such owner or occupier is not in a position to incur such expense. In such case the expenditure shall be borne by Government."

Clauses of penalties follow.

Sir Robert Sale gives (1910) the laws passed in several West Indian Colonies. From my experience (as a member of a committee which framed the municipal laws in the state of Bengal in India), I do not think that all of them are good or practicable; and Doyce admits that they have not become a dead letter. But I quote some of the clauses as examples.

"The occupier or owner of any premises shall keep such premises free of stagnant water liable to breed mosquitoes, and the presence of mosquito larvae in any dutchess of water, whatever its kind, shall be sufficient evidence that such water is stagnant."

"The occupier or owner of any premises shall keep such premises free of stagnant water liable to breed mosquitoes, and the presence of mosquito larvae in any ditch or pool of water, whatever its kind, shall be sufficient evidence that such water is stagnant."

In most of the clauses are simple and obligatory clauses.

Some specific provisions ought to be made to enable the sanitary authority to get up with sanitation, by ordaining to breed, ditches and hollows or any water, which failure, or any

likely to breed, mosquitoes; and also to compel Owners to cut undergrowth.
"The owner, or when required by the local authority, the occupier of every lot of land situated in a town or village district shall effectually drain the lot, and for that purpose shall (1) make such drains and drains on the lot as may be necessary for effectually draining the lot; (2) fill up all irregularities on the surface of the lot, and adjust the surface thereof, and if necessary raise the level of the surface thereof, in such a manner that the water received on the lot may flow into the drains without obstruction; (3) that no water can remain on any portion of the surface of the lot other than the drains; and (4) that the surface of the lot does not remain swampy. Provided that where the swampy state of any lot in any such district is occasioned by the main drains into which the drains of the lot discharge not having a sufficient outlet or a sufficient capacity to carry off all the water discharged into them, the owner or occupier of the lot shall not be liable under this section to raise the level of the surface of the lot if the level of such surface is as high as the average height of the level of the land surrounding such a lot for a distance of 20 rods (720 yards; a rod is a square measure); and provided that any owner may, with the consent of the local authority of that district in which the lot is situated, have a pond on the lot."

George-owned, British Guiana.

"All vats, tanks, or other vessels shall be screened with mosquito-proof wire-netting or other suitable material, so as to prevent the entrance into or exit of mosquitoes from such vats or tanks or other vessels." British Guiana.

Such regulations should, if possible, be included in the general Health Act, and not be left to the bye-laws of local bodies, which are often very incompetent. In my opinion British administration is generally much wanting in discipline, and tends to neglect the health and lives of the people for the sake of antiquated notions about the liberty of the subject.

65. Notes.—I will conclude this book with some miscellaneous notes on points of interest which have been studied while it was in the press.

(a) The thin film process.—For ordinary microscopic preparations, 1 c.c.m. of blood is spread out thinly over, say, 4 sq. cm. of area, and then examined either fresh or stained—at the cost of much time (section 8 (9)). Consequently I proposed the following method (15(1)). A quantity of blood, say 1 c.c.m., is spread over only about 1/16 sq. cm. of area, and allowed to dry. The haemoglobin is then washed out with water, and the residue, consisting of parasites, leukids, microls and the stroma of the haemoglobin, is stained by any appropriate method. We can thus reach 1 c.c.m. of blood in about 1/16
the time, or less, required for an ordinary preparation—but the parasites, especially Plasmodium, are apt to be overlooked unless the observer trains himself in the work. Originally I washed out the haemoglobin with water and then fixed and stained the smears as usual, but later I obtained better results by washing out with a lactic solution, then rinsing, and then passing over a weak solution of methylene blue. R. R. P. however, advocates the former procedure [1903], and L. Rogers [1908, p. 171] prefers first to fix and stain, and then wash out the haemoglobin with a very dilute solution of acetic acid—which leaves the outline of the haemoglobin without obscuring the view. All these methods are useful.kol are and over-extravasation of the smears are to be avoided, and the film should not be too thick.

Enumerative methods.—Very roughly, now in use. We count the number of parasites in a given number of fields of an ordinary preparation—giving an extraneous possible error, because we do not know the amount of blood in each field. Do we count the number of parasites found near a given number of white blood corpuscles? The total is the product of the two partial counts; and if the errors contained in the latter are both positive or both negative (which should occur in half the estimations), the total error may again be enormous. Errors caused by the haemacytometer in far from easy in the case of thick-film preparations, owing to the depth of the fluid column.

Since the beginning of this year (1904), the Advisory Committee of the Tropical Diseases Research Fund (Colonial Office) have granted considerable funds for the accurate study of cases of malaria in Liverpool, and Dr David Thomson and myself have commenced this study by elaborating improved "enumerative methods" based on my thick film process. A measured quantity of undiluted blood is made into a thick film preparation, and the total number of parasites contained in the whole of it is carefully counted. The quantity of blood used is measured by means of a graduated pipette or capillary tube. It is necessary that the blood should have a very low calibre to allow a small quantity of blood, such as a cm. of the capillary, to occupy a sufficient length of the tube to permit of accurate measurements being made. Then a tube of 1 cm. in diameter, and of 4 cm. in length, will contain 1 cm. of blood. In Wakelin Barratt points out that any one can make a suitable pipette by drawing out a fine capillary glass tube, measuring its calibre by the microscope, and calculating the length required to contain the given volume of
circle = square of diameter \( x \) by \( 0.7854 \), and area of ellipse = product of the two diameters \( x \) by the same figure. We are, however, making special tubes, measuring 1/4 c.mm. or more.

Mr. M. Greenwood, Jr., of the Lister Institute, informs me that the percentage of error is \( \frac{n}{n^2} - \frac{0.24} {\sqrt{n}} \) where \( n \) is the number of bodies actually counted in the measured quantity of blood. That the error = \( \frac{1}{\sqrt{n}} \) if we have counted 4,550 bodies, \( 1/\sqrt{n} \) for 1,138 bodies, \( 2/\sqrt{n} \) for 182 bodies, and \( 5/\sqrt{n} \) for 46 bodies. We must therefore always count enough bodies (mature or leucide) to reduce the error to any required percentage. Hence the measured quantity of blood should be small when the parasites are numerous, and large when they are scarce. We should perhaps allow \( \frac{1}{\sqrt{n}} \) error for the measurement of the blood, especially when very small quantities are taken. First sample should be rejected, and fixing before staining is demanded in order to avoid loss. The method is excellent for leucide.

3. Some results—Applied to a case of sleeping sickness the method disclosed, besides other facts, a regular periodic rise and fall in the number of trypanosomes occurring every seven to eight days—a phenomenon apparently not previously detected (Proceedings of the Royal Society, June 1906). With twenty-five cases of malaria some of our results are, briefly, as follows:

When lower than about 4,000 per c.mm., the sporida are not always numerous enough to cause marked rise of temperature (section 18 (8)). They may remain present in very small but determinable numbers during every day between relapses. A rise in their numbers to about 4,000 or more is generally accompanied by a febrile relapse and followed by a fall in temperature. A fall in the number of malignant sporida may be followed by such a abrupt and high rise that the said fall cannot be due to the death of the parasites, but must be caused by their retirement from the peripheral blood—that proving the hypothesis of Marchiafava and Ehrlich. Relapses may occur without a single crescent being found even after daily thick-smear examinations made during twenty-eight days, and the number of sporida counted during such relapses cannot be explained by parthenogenetic reproduction, unless we suppose that each crescent can produce some hundreds of spores. A rise in the sporid curve is often followed after eight to ten days by a corresponding fall in the crescent curve, suggesting that the latter require this period for development from the former; but sometimes no crescents at all are produced, even without quinine; or else the gamogenetic continuance of crescents suddenly. The rise of the...
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Crescent curve may be very rapid and continuous. This fall may be equally rapid at first, but often alternate with short more—suggesting continuous death and reproduction: but later the fall tends to be more gradual. Quinine (even in 2 gramme daily doses in a boy, sometimes and Ethyleen blue had no very decisive effect on the curve, when once formed. The crescents have never numbered more than 1/8 the highest number of spiroids. Of the three hundred 50,000 were the largest number found per c.mm. C. E. Ross, working with us, has documented parallel fluctuations of oocysts in urine and feces. Fundic and gastric contents applied to the spleen did not increase the number of crescents in the peripheral blood, and X-rays to the spleen did not prevent a relapse (compare Chapter IV.)

This method gives at the same time much more accurate diagnosis, and is useful for obtaining the parasite rate (section 45).

T. Darling has recently done some good comparative work at Panama, partly published 1910 and partly not mentioned to me by letter 1910. He counted the number of crescents in patients (by comparison with leucocytes), fed Anopheles on them, and then counted the argytes in the insects: and estimates that the mortality of the parasites in the stomach cavity is 52 (Paragraph 49). 6. arborescens, bred in laboratory, weighed 0:006 grammes before feeding, and 0:005 grammes after a moderate blood meal. He takes the average blood-meal to weigh about one milligramme, and from the number of oocysts counted in the blood, he estimates the number which must have been ingested during the meal. Thus he compares with the number of oocysts actually found. For example, he estimated that one mosquito should have contained 3,500 oocysts after three feedings: but it contained only forty. He thinks that fully half the ingested oocysts are captured by leucoids in the insect’s stomach— as I showed in 1895. In one mosquito he found 858 oocysts. He concludes that if the oocysts in a patient’s blood are less than about 12 per c.mm., they will not be numerous enough to infect mosquitoes. After experimenting on “a number of patients,” he thinks that 20 grains of quinine taken daily will reduce the number of crescents below 10. We have seen, however, that the crescent curve may fall quite irregularly, and sometimes very rapidly, without any quinine.

At my suggestion my brother, E. H. Ross, recently carried out the following experiment at Port Said, in parts from which mosquitoes have been entirely banished: 511 Culex fatigans, males and females,
were liberated from bottles in houses free from mosquitoes, and search was made to ascertain what became of them. Only 54, or 16%, were found, mostly dead, during the next day or two, after which the remainder disappeared entirely. Only three persons were bitten after the experiment—suggesting that the biting ratio (section 29 (3)) is very low, say 1/50.

(5). We have found three more successful mosquito inoculations of man, bringing the number up to 38 (section 29).

Case 36. J. Tsuzuki [1902].—Source, benign tertian. One of many infected Musca domestica bit healthy subject in Sapporo, Hokkaido, Japan, which is free of malaria on 24th August (?) 1902. Fever and parasites on 29th August.

Case 37. N. Jansco [1903].—Source, malignant. Anopheles (A. dirus) lit subject on 6th December 1901 in Hungary. One gramme sulphate of quinine given on seventh and eighth day after inoculation. Fever and parasites on 18th December.

Case 38. Ibid.—Same source and one Anopheles. Subject given same dose of quinine on eighth, ninth and tenth days after inoculation on 20th and 25th October (?) year. Fever on 4th November and parasites on the 5th.

Jansco also records three interesting negative cases obtained at the same time. Case 1 received 1 gramme of quinine daily from the second to the fourteenth day after inoculation, and remained well during nine months' incubation.

Case 2 received 1/2 gramme every morning on an empty stomach from ten hours before inoculation to the thirteenth day afterwards, and remained well during one month's observation.

Case 3 received 1.5 grammes quinine on fourth, fifth, ninth, tenth, fourteenth and fifteenth days after inoculation, and had no fever during one month's observation.

M. Glogner [1905] records two cases which he thinks were due to inoculation during vaccination.

(6). With reference to the attitude of Anophelines, Mr. Theobald informs me that the only species known to him of which the larva suspends itself in water like a Culicic larva is Mzorh. sinensis, and that Mzorh. culicifor is the only one of which the adult has an abnormal attitude. So far as he knows the larvae of all the species have no siphon.
(7) Regarding the enumeration of mosquitoes (section 29 (4)), I forgot to mention a method used at Panama and elsewhere, which consists in keeping note of the number of breeding-places found from time to time. It is, of course, a very vague method, but has the advantage of being easily practised by the working gangs or mosqui-токs. Such records give them no additional trouble and serve for a check upon their work.

(8) A. Eysell in the Arch. for Schiffs und Prophylaxis, Band X, 1910, argues that *Microbonia* is the same as the malaria-bearing mosquitoes of Kinoshita and also of Schuffner.

(9) Colonel W. G. King, the distinguished Sanitary Commissioner of Madras and Burma, informs me that from estimates which he has made regarding the cost of death and of sickness in India, he finds that the death of an adult costs Rs.20; of a child Rs.12.5; while a month's sickness of an adult costs Rs.9, and of a child Rs.4.5. As there are quite 10,000,000 deaths from malaria every year in India, with a corresponding amount of sickness, the total cost of the disease may be roughly computed from these figures.

ADDENDA TO THE SECOND EDITION, 1914

(10) Miscellaneous Notes.—Dr Malcolm Watson's book on the Prevention of Malaria in the Federated Malay States, referred to in section 35, has recently been published by the Liverpool School of Tropical Medicine, price 2s. 6d. It contains many details which could not be given in section 35, is fully illustrated, and should be read by all practical health officers. It has been very favourably reviewed by W. G. King in Nature of the 20th April 1914, and by others elsewhere. In Nature of the 9th February, however, a correspondence between C. A. Bentley and M. Watson was published, in which the former argued that the improvement at Klang and Port Swettenham was due not to the drainage, but to removal of overcrowding, resulting from the cessation of the construction works; but the latter easily disposed of this fancy. I mention the matter here only because Dr Bentley's letter has been published elsewhere without Dr Watson's reply; but may add that the former contains a fallacy very common in such literature. It begins by suggesting a hypothesis as a possible explanation; then accepts it without the smallest proof, and lastly confesses that the other explanation of the facts (which happens to be the true one) is
"an absurd fiction." Dr Watson has studied malaria prevention by all methods impartially during ten years over a large area of difficult country, and his conclusions deserve the closest attention. The results of the enumerative methods mentioned above have been published in the *Proceedings of the Royal Society*, and in full in the last ten numbers of the *Annals of Tropical Medicine and Parasitology* (Liverpool), in a series of articles by Drs David Thomson, E. H. Simpson, John Thomson, and myself. The work is of course mainly pathological, and a review of it will be found in my paper in the *Transactions of the Society of Tropical Medicine and Hygiene*, March 1911. The most important findings in connection with malaria are evidence of the theory of the parasitic invasion given in Chapter IV, and of the production of crescents mentioned in (3) above. These bodies are not directly affected even by large doses of quinine, and we have not found any other drug which destroys them quickly. Even for the asexual forms, about a gramme of quinine can be given daily for four to five days without causing total disappearance in a c.mm. of thick film—so that "prevention by treatment" probably requires much larger and more continuous dosing than is imagined at present. This should not discourage the measure, but should demand greater thoroughness in its application. The failures referred to by Watson and many others are doubtless due to insufficient dosing. In my opinion, infected persons had much better be kept at complete rest (even in bed) during one month's vigorous cinchonisation. Ehrlich's 606 has been well reported on for malaria, especially in Algeria, but the evidence is far from complete. We are now seeking other improvements.

Mr Edie, chemist to the Liverpool School of Tropical Medicine, has made at my suggestion *ferric nito* pills of cyanide of potassium contained in a solid floating medium. Experiments on larvae show that this poison is extremely deadly to them in solutions of such tenuity, that a man would have to drink 4 gallons (nearly 20 litres) of a solution at a time before receiving a lethal dose. The medium was made a floating one in order to prevent the pill sinking into the mud at the bottom of a pool. The pills can be used for waste waters by trustworthy and well-trained agents only, but should be extremely cheap and effective. Health officers who desire to try them should write to the secretary of the school or to myself, when samples with directions for use will be forwarded.

Tables of *statistical error*, calculated for various degrees of probability, from 1 to 1 up to .99999 to 1, will shortly be published in the *Annals*.
of Tropical Medicine for the use of sanitary and medical workers by Mr Walter Stott, Honorary Statistician to the Liverpool School of Tropical Medicine, and myself.

With reference to section 21, Rim and Boulot (Rev. Med. de l'Indo-China, 20th November 1907) publish a case in which a true relapse, verified microscopically, occurred in an old lady of seventy-five, who had been infected sixty years previously in childhood and who had lived in Paris for the last twenty years, certainly without relapse.


Sir David Bruce describes (Jour. Roy. Army Med. Corps, April 1911) an inspection of Baroda which he had just carried out for the purpose of studying the antimalarial measures there. Those who have felt any doubt as to the results of these measures should read the article.

(15). Malaria Prevention in India.—Several reports of local campaigns, showing that whatever the policy of the Government of India may have been, local officers are often doing their utmost against the disease, have been published. Among these I note only a few which I have been able to study.

Capt. A. B. Smallman, R.A.M.C. (Jour. Roy. Army Med. Corps, May 1911), well discusses prophylactic treatment. He judges that out of 275 men who were given 0.5 to 1.0 gram of quinine (+0.66-1.00 grammes) daily for four months, advised by myself, 11 or 4% suffered from true recurrence (not re-infection) in spite of the treatment (at Quetta). He finds that crescents take from nine to twenty days to disappear, uses enumerative methods, and estimates the number ingested by mosquitoes as being possibly 25,000 (vide above). In the same number of the Journal, Colonel G. P. Galloway, R.A.M.C., gives an excellent description of mosquito reduction among the military garrison of Bombay, with mention of difficulties, defects, cost, and results. He states that there was a great reduction in the numbers of the species of mosquitoes since 1908, but cannot compute the effect on the malaria owing to changes of regiments and corps. The cost was 300-500 rupees per acre (or 125-150) much less, I believe, than the £100 of invaliding a single soldier. Yet the Indian policy has been to declare that complete reduction is too expensive for practical use.
Captain M. F. Reaney, I. M. S., in a special official report (no publisher or date), has drawn up an excellent scheme for the town of Dinajpur. He says that a mosquito brigade was run for one year (1905-6) under Captain King, but was not continued after he left the station—another example of the discontinuity of such efforts in India. It remains to be seen whether Captain Reaney's scheme will have a happier fate.

Major J. C. Robertson, I. M. S., has given two most instructive reports on malaria in the towns of Najina and Saharanpur, with maps and charts. Both towns are surrounded by wet cultivation, and shown by a careful study both of death rates and given rates that malaria diminishes rapidly from the outskirts of the towns to the centres, where it is least. Dinajpur had 21,412 inhabitants, and Najina 66,254; and I estimate from the maps that the radius of the former is about 800 yards, and of the latter about 1,300 yards. He gives the diminution of the spleen rate in the former from 89% on the outskirts to 67% in the centre; and in the latter, from 75--90% on the outskirts to 61% in the centre. Actuals are unfortunately omitted; but the results are closely parallel to the death rates, and may therefore, I think, be taken as good evidence that the disease is practically perennial. The author, like Colonel King, wisely recommends the compulsory change of the suburban cultivation from wet to dry.

For many years past malaria prevention in India has centred round the so-called official experiment at Mian Jaffar, briefly described in section 54. In October 1909, at the Malaria Conference at Simla, a committee was appointed to report on the affair. This committee, consisting of two laymen and a medical man, spent only five days in the place, and completed their report a month later. The document did not reach me until the autumn of 1910, when it was criticised in the Lancet of the 5th November and the 3rd December 1910, by myself and Colonel W. G. King, respectively. Since then I have presented an exhaustive analysis of the whole subject to the India Office, to which Colonel King has added a full memorandum on malaria prevention in India.

The committee's report gives many details which, together with facts available from other sources, enable us to form a clear opinion of the affair. As stated in section 54, the experiment was commenced...
in April 1902, but gave no results which could be accepted by scientific men as being of any real value. Since 1904 the military authorities undertook much more thorough work; but, to judge by the committee's report, this was gradually allowed to fall off again to the smallness of the funds allowed, until, according to Colonel Rowan, the actual expenditure on the work was only about four rupees (6d. per annum)—and this for Anopheline reductions over eight square miles occupied by sixteen thousand people! The cost amounted to a few (about one gram) a head of population, and a small fraction of the considerable cost of the cantonment. The cantonment's funds were not sanctioned by the Imperial Government; no accurate records were kept, either of the cost or of the result of the operations; and yet the officials of the Indian Government have not scrupled to maintain that this was a scientific experiment carried out for the information of the whole world as to the practical utility of a new measure (mosquito reduction), designed for diminishing a disease which in India alone causes 1,000,000 deaths a year (by official estimate)! It would be difficult to refute me if I were to maintain that the whole affair was a public hoax arranged to save the authorities the cost and trouble of reducing malaria by the pretence that the suggested method had been tried and found to be impracticable.

Nevertheless, marvellous to relate, the chart of statistics given by the committee actually shows a great fall in the malaria rate during the active campaign of 1905-6. The committee attempt to parry this by showing that a similar fall occurred at Amritsar, where, they say, "malarial measures have not been adopted on a large scale." Unfortunately for them, I have found the following passage in the Annual Report of the Sanitary Commissioners with the Government of India, 1907: Appendix, page 21: "Amritsar. The Cantonment Committee remark that the ponds and hollows in the Cantonment are being filled up as funds are available... They say that the Cantonment suffers from shortness of funds, but still in ordinary years there is very little malaria that could be attributed to any condition existing in the Cantonment. The fact is that even the ruling monsoon season passed at Amritsar probably had a very marked effect on the malaria rate.

For the further details I must refer the reader to the letters in the Lancet just mentioned. The committee attempted to measure the mosquitoes and malaria by the usual random sampling, in which they ignore the statistical error. They do not discuss previous criticisms.
NOTES

They give wholly misleading accounts of campaigns elsewhere, and, in fact, show no adequate knowledge of the subject. While thinking that the few rupees spent at Mian Mir constitute an enormous effort, they forget altogether to consider the cost of the disease there, which, I think, amount to as much in one year as the antimalarial campaign has cost since it was commenced. But they are kind enough to conclude that “antimalarial measures combined with quinine prophylaxis offer great possibilities.” Except for the action of General Kitchener in 1905 and of the military medical officers, the whole affair has been, I think, a disgrace to Indian administration.

Colonel King’s memorandum just referred to will, I hope, be published before long. It is the work of a life-long student and director of Indian sanitation. He discusses the whole economical side of the subject in full, shows the immense cost of the disease, and the wisdom and pecuniary feasibility of adopting fundamental measures. It may not be generally known, but even at the present day India does not possess anything that can be called a sanitary service. Funds which should be expended in maintaining the health of the people are largely wasted in vain things, such as bani-education. Certainly most people like their children to be educated; but they also wish them to live. On comparing the expenditure on education and sanitation, however, one is driven to the conclusion that the Indian authorities prefer the former. Mian Mir has been the Sedan of the present sanitary administration of the country, and the system evidently requires complete reorganisation.

Some Historical Points.—The remarks on India contained in section 57 have evidently stimulated those touched by them to several anonymous “reviews.” A reply of mine to one of these has led to a furious rejoinder in which the anonymous author, evidently unable to answer my counter-criticisms, resorts to the usual personal abuse by pretending that I have not sufficiently acknowledged in Chapter I the assistance rendered to me in 1895 by Dr (now Sir) Patrick Manson (Indian Medical Gazette, April 1915). Chapter I is necessarily only an abridgment of the long history of malaria; and my acknowledgments of assistance rendered to me by Matsen, Lorenz, and many others have been published by me over and over again, especially and in full detail in my lectures [1905]. For instance, in my Proceedings Report [May 1906] I note: “These observations prove the mosquito theory of malaria as expounded by Dr. Patrick Manson; and in conclusion I should add that I have constantly received the benefit of his advice.
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addenda

during the enquiry, his brilliant induction so accurately indicated the true line of research that it has been my part merely to follow its direction. And I thanked Dr Laveran elsewhere in a similar and suitable manner.

Today, fifteen years after I wrote these words, I endorse every one of them. Since then I have read many scientific papers by juniors who have been assisted by the advice and views of their seniors, as, in fact, always happens; but, if I may say so, I have never read elsewhere any acknowledgment of such assistance more complete, or indeed so complete. The anonymous and ingenious reviewer of the India Medical Gazette, however, now uses this very passage of mine, and others like it, to maintain (a) that all my work was due to Manson, and (b) that because I have not said so in this book, and have not dedicated it to Manson (sic) I have "violated" in it "the unwritten laws of honour and of truth." I must therefore now describe again the exact extent of the assistance which he gave me.

Prior to why I failed in finding the parasites of malaria in man, as I have often stated and as many others failed. This was due to the facts that we could not obtain the recent descriptive Italian literature in India, and because we had been misled by several writers who had been describing artifacts instead of the true parasites. In 1904, however, Manson showed me the latter, as, I believe, others had shown them to him. This is a service (always acknowledged by me in the proper place) which every senior renders as a matter of course to every junior; but it does not give the former a claim to the credit of future researches made by the latter. If anyone were to make such a claim for me, I should repudiate it publicly at once as a matter of honour. In addition to this service, Manson occasionally supplied me with literature, and also urged Government to place me on special duty. I received similar help from others, and the Government of Madras and the Maharajah of Patiala also offered to place me on special duty. It does not detract from the thanks due to Manson to observe that such services also are always, let us hope, rendered by seniors without constituting a claim to researches made by the latter; and I believe that Sir Patrick Manson himself would be the first to repudiate such a ridiculous suggestion.

Now as to the actual conduct of my Indian researches of 1895-8. As I have stated over and over again, they were based on Manson's induction of 1904, and also on Laveran's mosquitoe hypothesis of nine.
years before this. That is to say, I inferred as a working hypothesis (a) from Laveran that mosquitoes might be connected with malaria, and (b) from Manson, more exactly, that the so-called flagella very probably infect the insects. But the anonymous and ingenuous reviewer is not content with this, and exclaims, "Why ask Major Ross why he neglected to indicate that those researches were carried out entirely on the instructions delivered to him personally by Sir Patrick?" For the simple reason that the statement is "entirely" untrue. When I gave thanks for advice tendered to me, I did not say that I always or even usually followed that advice. When I said thanks I had nothing to do but to follow Manson's induction, I did not say that I followed it by his methods and according to his instructions. I did not do so. I received from him and his induction merely the general indication to feed mosquitoes on patients, and then to try to follow the so-called flagellated spores into the insects' tissues: but, as already explained in section 5, and at full length in my lecture (1895), this method was abandoned after a few months, because it was found impracticable. My methods (which were not advised by Manson) were (a) to keep the fed insects for several days and then to search them for any exceptional parasites which may have developed in them; (b) to try to infect persons by drinking water in which fed mosquitoes had been kept; and (c) to try to infect persons by the bites of the insects. It was fortunate that I made the change so early, because Manson's method would have led only to failure, owing to the fact that the so-called flagellated spores were not such at all, but were spermatozoa; and it was my method (a) which finally gave success. All this has been clearly set forth in my earlier writings, as the anonymous and mendacious reviewer, who has studied them with all the assiduity of personal animus, well knows. It may be thought that I had received full instructions regarding technique. This also is untrue. I learnt so little regarding mosquitoes that I did not even know the zoological name of the group to which they belong till 1898; and when I commenced work in 1895, I was told that they live for only five days—vide Manson [1894 and 1896]; and it was I myself who found out how to keep them alive for longer periods. I obtained no literature or instructions, much less any demonstration, on the methods of dissection, the anatomy, the feeding, keeping, the diseases, and the classification and zoological characters of the insects—all of which I had to teach myself as best I could. The leading and rough grouping of them I commenced to study years previously. To this present day
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I do not know the technique employed by Manson in his work on *Filaria bancrofti* in mosquitoes in India; and of course my technique was necessarily far more delicate. Moreover, it is not exact to say (as has been said) that my work was published by Manson. Owing to official delays, I was obliged to ask him to bring out preliminary notices of it; but the full details were published by myself. Lastly, I may point out that one could have done in England what I was doing in India—the patients and the mosquitoes were present, and the parasites have been easily cultivated in mosquitoes in Haidarabad and Madagascar. While therefore I freely acknowledge that I had on the subject thirteen years in advance of that which I made then and subsequently am sufficient, and that I was not prepared to admit that my work was done by any one but myself. I may add that this book is dedicated to all genuine workers on malaria, among whom Manson is, of course, one of the most distinguished.


The mathematical treatment adopted in section 28 has been met with some questioning by critics. Some have approved of it, but others think that it is scarcely feasible owing to the large number of variables which must be considered. As a matter of fact all epidemiology, concerned as it is with the variation of disease from time to time or from place to place, must be considered mathematically, however many variables are implicated, if it is to be considered scientifically at all. To say that a disease depends upon certain factors is not to say much, until we can also form an estimate as to how largely each factor influences the whole result. And the mathematical method of treatment is really nothing but the application of careful reasoning to the problems at issue. I propose, therefore, in this section, to give the calculations of section 28 a fuller treatment, in a manner which will be useful to students not only of malaria, but of other diseases, and in fact of other lines of work; and am convinced that many readers will be able to follow the work without difficulty.

The application of mathematics to epidemiology and even pathology has suggested itself to me (and perhaps to others) for many years; and when I came to write my *Malarial Report* [1908], I found myself driven to make some attempt in that direction. I suggested there the term *Pathometry*, which can be applied to all mathematical study of infectious disease whether of the individual or of the community, and attempted the first applications to the time-to-time variation of malaria.
The principal difficulty lay in the careful consideration required to separate the numerous variables and to bring them into working shape; and this was effected by putting them into the form of a continued product of ratios, \( b_s b_a b_i p \). From this the elementary difference equation of section 28 (2) was deduced. This is one of the first second and degree. I obtained (but did not publish) its solution (by my Verh-Functions) in the form of a series which when \( \delta \) is small reduces to a simple exponential function \([1908, p. 35]\). I gave also the static formula of section 28 (5), showed that the Anopheline factor \( \phi \) must be large enough if the malaria ratio is to continue, and worked out several examples; but the report was written too hurriedly for further work. The subject was taken up again for this book at the end of 1909 with the results given in sections 28, 30, 30 (15), etc.—leading to the following laws:—

(a) The disease will not spread if the constants are too low.

(b) It will tend to reach a fixed limit depending on these constants.

(c) A small change in the constants (e.g. the Anopheline factor) may produce a great change in the malaria (section 30 (15)).

Nevertheless, as explained at the end of section 28, many variables, such as the effect of repeated bitings, were not considered.

Meanwhile I had asked Professor Karl Pearson for assistance, and he very kindly requested Mr H. Waite, M.A., B.Sc., to study the subject. I am extremely indebted to these gentlemen for their valuable help, which will give the reader more confidence in the results obtained. Unfortunately Mr Waite was not able to complete his studies until this book was published; and his article appeared in Biometrika, vol. vii. No. 4, October 1910. He had thus seen my Mauritius Report \([1908]\), but not this book; and it will therefore be interesting to compare our results.

(d) Mr Waite's Article.—In my work I have hitherto taken the month as the unit of time during which the numbers of infected persons and of infective mosquitoes are supposed to remain constant. That is, I supposed that at the beginning of the month there were \( m \) infected persons and \( s \) infective mosquitoes with protospores in their glands, ready to infect fresh persons. During the whole month these would deliver \( b_s b_a b_i p \) infective bites; but only a proportion of these would be inflicted on healthy persons, so that the increase in the number of infected
persons during the month would be $66 \times (1 + 0.063)$. But at the same time, I estimated that a sixth of the human cases existing at the beginning of the month would recover by the end of it; and I thus obtained equation (4) section 28, which shows the result of the gain and the loss during the entire month. But of course this is a considerable interval of time, and the truth would be that the number of infective mosquitoes, of recovered persons, and of infected persons would be varying slightly from day to day. On the other hand, the number of infective mosquitoes found on a given day does not depend, as suggested above, on the number of infective persons found on the same day, but on the number found from one to, say, three weeks previously; and also the newly infected persons would not be able to influence the equation by infecting fresh mosquitoes until from two to three weeks—to allow for the incubation period and the production of parasites. On the whole therefore—I regret I omitted to explain this—I thought that the one-month unit of time would be best because it would cover the periods just mentioned. Moreover, unless the malaria rate was varying with perhaps unnatural suddenness, the number of infective mosquitoes and persons would not change much during the month. In fact, we shall reach the same result if we suppose that all the events—the bites and the recoveries—are concentrated into one day in each month and do not occur again until the same day next month. And this position must be approximated to more and more as the disease approaches the static condition, when time-to-time variations are taken as ensuing.

Mr. Wash's very interesting article is simply written, contains diagrams of curves and a number of carefully calculated examples, and will do much to convince the reader of the utility of such work. Referring to my section 28, he says: "From a comparison of the two accounts [his and mine] it will be seen that there is complete agreement between us on the essential and fundamental points, but some difference in numerical details. This difference is due to an attempt on my part to treat the question by fuller and more rigid mathematical methods, which would be out of place in a treatise written from the medical standpoint, while the simpler methods employed by Professor Ross give results which are sufficiently accurate for practical purposes." The difference in numerical details is, as he explains, due to his having taken for a unit not the month selected by me, but the interval between two consecutive infecting bites. He adopts my continued product of ratios, showing with some small elaboration
which it is unnecessary to repeat here), and writes \( n = \frac{f \cdot \text{imp}}{H} \).

\( n \) is the number of infected bites delivered (as before) during entire month. But he now divides the month into \( m \) month intervals, each of which he takes as his unit of time; and estimates the recovery rate by my standard, not for the entire month as I did, but for the \( m \)th part of a month; and so forms his differ equation.\(^1\)

As he rightly points out, this shorter unit of time enables us to deal more continuously both with the increase of malaria due to bites, and with the decrease due to the recoveries; but there is a variable, namely, the number of infective mosquitoes, \( n \), which, in turn, depends on the malaria rate of a few weeks previous. Would not therefore be more correct to employ the same unit of time for the variables together? By keeping \( n \) constant while \( m \) and \( r \) both the increase and the decrease of the malaria rate are neglected too slowly. Thus the changes shown by Mr Waite's figures are so rapid as mine (just as he says); but I am not clear that they approximate nearer to the truth.

For static malaria Mr Waite obtains the following equation (in the terms of section 27):

\[
a = \frac{c}{1 - \frac{c}{1 + \frac{r(1 - m)}{2111p}}}
\]

This ceases to hold when \( 2111p > 1 \); that is, when there is \( 1 \) than one inoculation in the month (see end of section 27), in which case the results are indeterminate. The constant \( r = 43.5 \) and \( p \) little higher than my lowest malaria-producing limit of Anopheles, namely, 39.6. The form of my equation for static malaria (section 37) is evidently the same, allowing for the difference in the constant \( c \) the first term of the above, which is obviously the most effective on the rate.

The following table shows the relation as given by him (page 4) between the number of malaria cases \( (\text{fl}) \) and the number Anophelines per man \( (\text{a}) \) for static malaria in a population of 1,000:

\[
\begin{array}{cccccccc}
\text{a} & 40 & 44 & 49 & 54 & 59 & 63 & 68 \\
\text{fli} & 20 & 24 & 29 & 34 & 39 & 43 & 48
\end{array}
\]

Observe the great rise in the malaria rate compared with the same of the Anophelines. The latter would scarcely be detected by present methods—so rapidly passed out. In section 37 (14) of the former would be a severe epidemic. \(^2\)

\(^1\) See (9) below.
The Problem of Happenings and Becomings.—But it is always advisable to commence such studies from the widest possible point of view. I will therefore now discuss a much more general issue, which concerns the malaria problem as a particular case, and which, though still incomplete, may be of use to the sanitarian in many ways. We shall deal with time-to-time variations not only of malaria, but of all disease, and not only of humans, but those of any living organism. Still further, as infection is only one of many kinds of event which may happen to such organisms, we shall deal with happenings in general.

Problem I.—Consider a population of any organisms living in an area, and suppose that in unit of time some event happens to a constant proportion of them. Suppose also that the population is being perpetually changed by a constant birth-rate, death-rate, immigration rate and emigration rate. Then, at the end of a given period, what proportion of the population found living in the area will be also found to have been affected by the happening; and to what proportions will the event have happened once, twice, etc.? The happenings may be some kind of accident or disease, birth, death, marriage, or anything else that we can think of—vacation, receipt of bequests, conversion to some creed, etc. But we now observe that they may be of two kinds, some which occur once for all, and those which affect the subject for some given period, after which they cease to affect him. In the latter case we have to deal with happenings or events rather than simple happenings; and this group contains diseases from which recovery and loss of immunity take place—which leads to another problem.

Problem II.—Suppose that in addition to the data of Problem I a constant proportion of the affected class revert to the unaffected class in unit of time, how will the proportions then stand at the end of the given period? Both problems can be solved together as follows:

(a) Solutions of the Equations.—Let \( P \) be the total population at the end of the period; \( a, \), the proportions of them to which the happening has not occurred at all; \( b, \), the proportions to which it has occurred once; \( c, \), the proportion to which it has occurred only twice, and so on. And let \( i \) be the whole number of those to which the event has occurred.
Notes

To begin with we shall consider only \( a \) and \( a^* \), that is the total unaffected and the total affected individuals. And obviously,
\[
\rho = a + a^*.
\]

Let \( \nu \) be the variation in unit of time due to births, deaths, immigration and emigration among the unaffected, \( a \); and \( \tilde{V} \) be the similar variation among the affected, \( a^* \). Let \( a_0 \) be the proportion of the unaffected which become affected in unit of time, and \( a^*_0 \) be the proportion of the affected which become unaffected (i.e., which revert or recover) in unit of time. And for brevity let \( \bar{\alpha} = \lambda - \lambda \)
and \( \bar{\beta} = 1 - \bar{\alpha} \). Then,
\[
\begin{align*}
\dot{a}_0 &= \nu a + \tilde{V} a^* \\
\dot{a}^*_0 &= \nu a + \tilde{V} a^* \\
\dot{a}_0 &= \nu a + \tilde{V} a^* \\
\dot{a}^*_0 &= \nu a + \tilde{V} a^* \\
\end{align*}
\]

These difference equations are obviously true because the gain of one group is the loss of the other group, and the total population is composed of the sum of the two groups without the factors \( \tilde{\alpha} \) and \( \tilde{\beta} \).

We proceed to solve them without further discussion at the moment.

Eliminating \( z \), from the first two equations we have,
\[
\begin{align*}
\dot{a} = \nu a + \tilde{V} a^* \\
\dot{a}^* = \nu a + \tilde{V} a^* \\
\end{align*}
\]

Hence
\[
\begin{align*}
\dot{a} = \nu a + \tilde{V} a^* \\
\dot{a}^* = \nu a + \tilde{V} a^* \\
\end{align*}
\]

That is
\[
\begin{align*}
\dot{a} = \nu a + \tilde{V} a^* \\
\dot{a}^* = \nu a + \tilde{V} a^* \\
\end{align*}
\]

Similarly
\[
\begin{align*}
\dot{a} = \nu a + \tilde{V} a^* \\
\dot{a}^* = \nu a + \tilde{V} a^* \\
\end{align*}
\]

The solution of this difference equation is composed of the roots of the ordinary algebraic quadratic
\[
\begin{align*}
\lambda^2 - (\nu + \tilde{V}) \lambda + (\nu \tilde{V} - \nu \tilde{V}) = 0 \\
\lambda^2 - (\nu + \tilde{V}) \lambda + (\nu \tilde{V} - \nu \tilde{V}) = 0 \\
\end{align*}
\]

Let \( \lambda \) and \( \lambda^* \) be those roots. Then
\[
\begin{align*}
\lambda = \sqrt{\nu} + \sqrt{\tilde{V}} \lambda^* = \sqrt{\nu} + \sqrt{\tilde{V}} \\
\lambda = \sqrt{\nu} + \sqrt{\tilde{V}} \lambda^* = \sqrt{\nu} + \sqrt{\tilde{V}} \\
\end{align*}
\]

where \( \alpha, \beta \), and \( \gamma \) are constants to be now determined. Putting successively \( \lambda = \alpha \) and \( \lambda = \beta \) in the equations (6), we have
\[
\begin{align*}
\alpha &= \nu + \tilde{V} \\
\alpha &= \nu + \tilde{V} \\
\end{align*}
\]

and
\[
\begin{align*}
\beta &= \nu + \tilde{V} \\
\beta &= \nu + \tilde{V} \\
\end{align*}
\]

and
\[
\begin{align*}
\gamma &= \nu + \tilde{V} \\
\gamma &= \nu + \tilde{V} \\
\end{align*}
\]
From these, \( c, C, d, D \) can easily be obtained, and we have finally

\[
(X-Y)a_1 = (a_1-a_0 Y)X' - (a_1-a_0 X)P
\]

which

\[
\begin{align*}
    a_1 &= a_0 + hT\alpha, \\
    a_0 &= \beta_1 + hT\alpha, \\
    P &= \alpha, \\
    P &= \beta
\end{align*}
\]

The algebraic quadratic (c) is a perfect square if \( hT\alpha = a_0 \); in which case we have

\[
X = \sqrt{\alpha} Y = \beta P
\]

The quadratic may also be written in the form

\[
\begin{align*}
    X &= \sqrt{\alpha} Y = \beta P \\
    (X-Y)^a &= (a_1-a_0 Y)X' - (a_1-a_0 X)P
\end{align*}
\]

This also is a square if \( hT\alpha = a_0 \), or in small enough to be negligible—i.e., which occurs when \( \alpha \) and \( \beta \) are the same or nearly the same, or the unit of time taken is small. In this important case

\[
X = \sqrt{\alpha} Y = \beta P
\]

Otherwise the roots of the quadratic may be irrational. They will always be of the form

\[
X = P + Q, \quad Y = \beta P + Q,
\]

where

\[
\begin{align*}
    X &= \sqrt{\alpha} Y = \beta P + Q \\
    (X-Y)^a &= (a_1-a_0 Y)X' - (a_1-a_0 X)P
\end{align*}
\]

The equation (c) may be written

\[
(X-Y)a_1 = (a_1-a_0 Y)X' - (a_1-a_0 X)P
\]

and

\[
X = \sqrt{\alpha} Y = \beta P
\]

Hence, since

\[
(X-Y)a_1 = (a_1-a_0 Y)X' - (a_1-a_0 X)P
\]

the equation (c) may be expanded with the radical dropped.

\[
(X-Y)a_1 = (a_1-a_0 Y)X' - (a_1-a_0 X)P
\]

\[\text{etc., etc., on expanding which the radical disappears.}\]

(g). The Variational Equations. This solution holds only when \( \alpha, \beta \),

\( A, B \) are constants for the period under study. We have now to discuss these constants more exactly. Beginning with \( \alpha \) and \( \beta \),

Let \( n, m, e, \xi \) denote respectively the nativity, mortality, immigration

and emigration ratios in unit of time among the above mentioned
N, M, I, E the similar ratios among the afflicted. Thus it is best to write

\[ V = (I + N)(I - M)(I + I)(I - E) \]

Here the symbols on the right denote positive numbers, the magnitude of which depends on the magnitude of the unit of time for which they are taken. If that unit is one year, for instance, and the annual nativity is 25 per mille, and the annual mortality is 20 per mille, we should have \( n = 0.25 \), \( m = 0.20 \). But if we reduce the unit to a month, a day, an hour or less, we must also reduce the values of \( n \) and \( m \) and the same observation applies to the other constants.

If the unit of time, or the constants themselves, are very small, their products may be neglected, and we have

\[ V = (I + N - M + I - E) \]

Or we may proceed as follows. We have

\[ V = (I + n)(I - m)(I + i)(I - e) \]

Now suppose that all the symbols refer here to an infinitesimally small unit of time, and suppose that \( t \) is the number (extremely large) of such small units contained in some finite unit such as one day. Then each of the factors takes the well-known exponential form, and we have

\[ V = e^{t(n - m)(i - e)} \]

with a similar expression for \( V \). Hence, of course, the symbols refer, not to the infinitesimal unit, but to the finite one. The two terms of the expansion of the exponential give the same result as (k) above.

It is necessary to assume that each of the variation factors may be different for the two groups \( a \) and \( b \). For example, the mortality and emigration may be much greater, and the nativity and immigration less, in certain diseases. I have therefore used different symbols for \( v \) and \( V \), and for their constituents. Also \( n, M, i, E \) are always not greater than unity.

(6) The Happening and Reversal Constants—Consider now the following equations.

\[ a_1 = \frac{(1 - h)(i - e) + (1 + h)(i - e) + (1 - h)N + (1 + h)n}{h}, \]

\[ b_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]

\[ c_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]

\[ d_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]

\[ f_1 = a_1 + b_1 + c_1 + d_1, \]

\[ g_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]

\[ h_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]

\[ i_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]

\[ j_1 = \frac{(1 + h)(i - e) + (1 - h)(i - e) - \frac{1}{h}, \]
These are evidently the same as equations (a) above; but in greater detail and without the mortality, immigration and emigration ratios.

Looking first at the equation for \( f \) we see that it is the sum of the others, and that \( a_n \) consist of \( a \) and \( s \), plus the births that have occurred to the two groups in the interval of time between \( t \) and \( t+1 \)—just as it should do. The factor \( b \) denotes the ratio of individuals to which the happening has occurred to the same unit of time, and to which \( f \) has not occurred. Thus \( b_c \) is the proportion of the affected group which has occurred to the affected group in the unit of time, and \( (1-b) \) the proportion which remain behind.

The second and third terms of the equations denote a similar change among the offspring derived from the two groups (\( x \) and \( y \))—it being assumed that the offspring of the affected are not affected, and the factor \( (1-s) \) those that do not revert. Since the happening may occur again to some of them that revert immediately after reversion (as it may occur to the new born immediately after birth) it is necessary to include the term \( b \), but that and the terms \( b_c \) and \( (1-b) \) will generally be small. The equations therefore seem to include every possibility. They may be written

\[
\begin{align*}
\alpha_n &= (1-b)(1+y_n) + (1-y_n)X_n\alpha_n \\
\alpha_n &= k(1+y_n) + (1-y_n)X_n\alpha_n
\end{align*}
\]

But

\[
X_n' = \left(1 - \frac{1}{1+y_n} \right)(1+y)
\]

and

\[
\delta(1+y_n) + (1-y_n) + (1-y_n) + (1+y_n)
\]

Hence, putting

\[
\delta = \frac{1}{1+y_n} \quad k = 1 + y_n \quad X_n = 1 + y_n \quad \alpha_n
\]

have

\[
\begin{align*}
\alpha_{n+1} &= \delta + (1-y_n)X_n\alpha_n \\
\alpha_{n+1} &= k(1+y_n) + (1-y_n)X_n\alpha_n
\end{align*}
\]

Lastly, to bring in the mortality, immigration and emigration factors, we have

\[1\text{ I think that this is the correct method. It is useful to see to what extent moves the affected stock.}\]
shown in equations (f), we have only to multiply $a,$ by $m/n$ and $x,$ by $N/T E,$ and we get
\[a \times \frac{x + 1}{a} = b + 2,\]
\[a \times \frac{x + 1}{a} = b + 2 E T E.\]
\
as in equations (a), which have already been solved. Thus
\[H = h - h'R,\]
\[H' = h + h'R.\]
\
Also, as $H = h - h'R,$ the middle in the roots of the quadratic equation (c) may be written
\[4Q' = \left\{ v + h'RV - \frac{1}{v - V} \right\} - 4v.l/RV\]

and we obtain the following values of $xQ, X,$ and $Y$ for the study of particular cases:

if $y = V, X = v, Y = v R F, X = v R F$

if $a = 0, X = v, Y = v R F, X = v R F$

if $h = 0, X = v, Y = v R F, X = v R F$

if $h = 0, X = v, Y = v R F, X = v R F$

if $x = 0, X = v, Y = v R F, X = v R F$

if $a = 0, X = v, Y = v R F, X = v R F$

if $h = 0, X = v, Y = v R F, X = v R F$

if $x = 0, X = v, Y = v R F, X = v R F$

(2) The Epidemiological Case.—We have thus obtained integral expressions for $a, x,$ and $p,$ in terms of $v,$ and of the ten independent constants $h, x, n, n, n, n, N, M, F,$ and $E,$ and the finite form in which they have been obtained has this advantage over the infinitesimal form, that it enables us to employ any unit of time we please—as may sometimes be required for particular cases. The reader can now study some such cases—accidents, diseases, etc.; and it will be seen that each disease will have its special equation. I must, however, confine myself to the particular case of equation (g), when $v = V,$ that is, when the kind of happening under consideration does not greatly modify the birth- and death-rates of the affected group. This may be accepted for the present in the case of malaria, especially since the equation $v = V$ does not imply that each factor in $v$ equals each factor in $V.$ The case includes also most of the flatter kinds of disease; and the formulae will be useful for a number of calculations required for public health.
(i). From equation (2) if \( t = 1 \), \( \Delta = \tau \) and \( \lambda = (b - H)/\tau \), and equations (6) then become:

\[
(b + H)\pi = (bH + H\pi) + (bH - H\pi) e^{-\tau} \\
(b + H)\pi = (bH - H\pi) e^{-\tau}
\]

The constants in terms of the variables \( m \) are:

\[
\Delta = (e^{-\tau})^{(t + r) - \tau} \\
\Delta = (e^{-\tau})^{(t + r) - \tau} \\
\Delta = (e^{-\tau})^{(t + r) - \tau} \\
\Delta = (e^{-\tau})^{(t + r) - \tau}
\]

By substituting \( \pi \) for \( \pi \) we have:

\[
\pi - \tau \pi = \tau \pi - \tau
\]

Useful forms are

\[
\pi = \tau = \frac{1}{(t + r)} \left[ (e^{-\tau})^{(t + r) - \tau} \right] \\
\pi = \tau = \frac{1}{(t + r)} \left[ (e^{-\tau})^{(t + r) - \tau} \right]
\]

and if \( t = \tau \) exactly,

\[
\pi = \tau = \frac{1}{(t + r)} \left[ (e^{-\tau})^{(t + r) - \tau} \right]
\]

Obviously \( m_0 \) and \( n_0 \) are the numbers of the smugget and the affected groups at the beginning of the enquiry, and when \( t = \tau \) and therefore \( m_0 = n_0 \) we suppose that the enquiry begins at the same time as the happenings. When \( t = \tau \) and \( \lambda = 1 \), the population remains constant in number.

(ii). As stated in (5) above, if the unit of time taken is very small, the elements are also very small and their products may be neglected.

Thus \( \frac{(e^{-\tau})^{(t + r) - \tau}}{t + r} \) becomes \( (e^{-\tau})^{(t + r) - \tau} \) and if \( \pi = \tau \), we have

\[
\pi = \tau = \frac{1}{(t + r)} \left[ (e^{-\tau})^{(t + r) - \tau} \right]
\]

which is useful for quick calculation when \( \tau \) is not too large. If the
unit of time is indefinitely small, \( v' \) and \( z' \) can be put in the exponential form of equation (6), and we have

\[
\eta = \left( \frac{h}{1-h} \right) \left( 1 - e^{-\left( (1-h) \eta + \sigma \right) t} \right)
\]

See also (a) below.

As \( \frac{v' - v}{v'} \) or \( \frac{z' - z}{z'} \) decreases without limit as \( t \) increases, we have ultimately, if the elements remain constant and \( t \) is large enough, \( \eta = N + \eta \left( 1 + \eta \right) \). That is, \( \eta \) reaches a fixed limit. But if the \( \eta \) is very small, even when referred to a finite unit of time, \( t \) may have to be very considerably large before this limit is nearly approached.

Although \( v = V \), I have still retained both symbols where necessary, because this equivalence does not always shown that each element in \( v \) is equal to each element in \( V \). For the same reason I have retained \( N \). The asymmetrical position of this element in the equations is due to the fact that according to the postulate of (6) the offspring of the affected group are born unaffected, and are therefore not subject to recovery. On the other hand, the immigration element does not possess this asymmetrical position, because the immigrants are supposed to be affected in the same ratio as the considered population. Moreover, the equations (a) will hold approximately (equation \( g \)), even if \( v \) does not exactly equal \( V \), if \( h' + V \) is small enough to be neglected in comparison with \( (1 - h) \eta + V \); and when the unit of time taken is small enough, the former expression tends to vanish while the latter approaches \( x \).

The following are some special cases. If we retain only \( a \), equations (c) and (f) become

\[
\eta = \left( \frac{h}{1-h} \right) \left( 1 - e^{-\left( (1-h) \eta + \sigma \right) t} \right)
\]

so that, if \( t \) is large enough, \( \eta = v \) and \( \eta = z \), that is, there are no reversions, the whole of the original population becomes affected. If we retain also all the other factors except \( a \), \( \eta \) and \( \sigma \), we have

\[
\eta = x \left[ \frac{v}{1-v} \right] \rightarrow z = \left( 1 - e^{-\sigma t} \right) \eta
\]

(iv). If we retain only \( z \),

\[
\eta = x \left[ \frac{z}{1-z} \right] \rightarrow z = \left( 1 - e^{-\sigma t} \right) \eta
\]

The latter equation gives the decrease in an affected population by the
ADDENDA

reversions alone in the absence of any fresh happenings—as already used in sections all and in Mr. Walsh's article to infer the recovery ratio. The mortality, immigration and emigration elements can be added as in (90).

The reversion ratio may be a function of the happening ratio as in the case of divorce and marriage; but in disease it is generally independent, being a pathological element, while \( r \) is an epidemiological one. For example, in a disease in which \( 90\% \) of the cases "recover" in 10 days and \( r \) is the daily recovery ratio, \( r = 0.9 \). Yet the reversion ratio may be large or small. See also (32,5) below for a definition of the term in connection with disease.

(5). Examine only \( k \) and \( r \), and if \( r = a \),

\[
\frac{\Delta x}{\Delta t} = k (1-x)(1-x) + \frac{1}{2} \left(1 - \frac{1}{2} \right) (1-x) \cdot \cdot \cdot (1)
\]

Thus if \( r = \frac{1}{10} \) per day and \( k = 10 \) per day, the number of infected people in each of the first five days would be about 8, 17, 21, 25, and 29, rising to 68 in ten days and to nearly 171 subsequently. If however \( k = 1 \), the value of \( x \) would rise to 90\% in the first day, and would subsequently asymptote to 90\%.

It should be observed that, as long as \( k \) and the other elements are constant, the rise in the value of \( x \) is continuous, but is rapid at first and slower as it approaches the final limit.

The coefficient \( \frac{k}{(1+r)^2} \) in the expression for \( x \) may be called the modulus of the happenings and be denoted by \( \epsilon \), so that \( x \) when \( r \) is large enough. This may be named the static value of the happening-equation.

(8). Repeated happenings.—But in subsection (3) we asked “to what proportion of the population will the event have happened once, twice, thrice, etc.” And in subsection (4) I sketched the following table, taking \( \epsilon \) = \( \epsilon_0 \). But in subsection (3) the event has not happened at all; \( \epsilon_0 - \epsilon \), the numbers so while it has happened once; \( \epsilon_0 - 2\epsilon \), twice; \( \epsilon_0 - 3\epsilon \), thrice; etc.; and 0, the number of those to which the event has occurred any number of times. We have obtained such the values of \( \epsilon_0 \) and \( \epsilon \). It will be now useful to consider these as \( \epsilon_0 \) and \( \epsilon \). They can be obtained from the following difference equations:

\[
\begin{align*}
A_{n} & = B_{n-1} + (1-k) B_{n} + C_{n-1} + D_{n} \\
C_{n} & = A_{n-1} + (1-k) C_{n} \\
D_{n} & = B_{n-1} + (1-k) D_{n} \\
A_{0} & = 0, B_{0} = 1, C_{0} = 0, D_{0} = 0.
\end{align*}
\]
letters previously used—which are no longer required). Then the same equations for the two species will be
\[ \frac{dz}{dt} = -(\epsilon - \delta) z + (\alpha - \beta) z' \]
\[ \frac{dz'}{dt} = -(\epsilon' - \delta') z' + (\alpha' - \beta') z' \]
(We could continue to use \( z \) here if we like). There may be written
\[ \frac{dz}{dt} = (N - r) z + (N + r') z' \]
\[ \frac{dz'}{dt} = (N' - r') z' + (N' + r) z' \]
(\( ab \)).

Now \( \alpha \) and \( \alpha' \) represent the infection rates in the two species of animals; and the infection—that is, the parasite common to both species—passes from one species to the other and back again. Hence there must be a relation between \( \alpha \) and \( \alpha' \) and between \( \beta \) and \( \beta' \).

When \( z' = 0 \), then also \( z = 0 \), since no infected animals of the \( z' \) species are left from which the infection can be conveyed to the other species; and if \( z' \) is large we may expect (and, indeed, find) that \( z \) also is large.

And precisely the same things may be said of the relation between \( \beta \) and \( \beta' \). Hence we may assume, to begin with, that the relation is without a free constant and is of the first degree; and therefore put
\[ \alpha = k' z' \]
\[ \alpha' = k z \]
where \( k \) and \( k' \) will be discussed presently. Substituting these values for \( \alpha \) and \( \alpha' \) in equations (\( ab \)) and eliminating \( z' \) between them, we obtain
\[ z (1 - r) k (1 + N) k' (1 + N') - (1 + N) k z (1 + N) k' (1 + N') \]
with a similar equation for \( z' \). From these, if the elements are known, the static numbers of affected animals of both kinds can be found.

\( \epsilon \) and \( \epsilon' \) represent the infection rates in the two species of animals; and the infection—that is, the parasite common to both species—passes from one species to the other and back again. Hence there must be a relation between \( \epsilon \) and \( \epsilon' \).

That is to say, both \( \alpha \) and \( \alpha' \) occur during a very short time unit or element. To calculate \( \alpha \) and \( \alpha' \) for this group we proceed as follows:

First take a very short time unit (say 1 minute); and suppose that
\[ np \]
is the number of persons bitten and
\[ ml \]
the number of mosquito (or other animal) bites during it. Then as the time unit is so short we may grant each insect has fed only once during it and has bitten only one person; and that, conversely, each person has been
ADDENDA

bitten only once during it, and by only one bite. Hence the number of persons bitten during the time unit equals the number of terms that is, \( pe = pf' \). As \( F \) is a ratio which applies to all or any of the inputs present it applies also to the infected ones, that \( n', \) \( n'' \) will be the number of infected mosquitoes which bite during the time unit and will also be the number of persons that are bitten by each. But not all the infected mosquitoes, \( C \), will also be active; let \( f'1 \) be the number of the latter. Then \( f'2 \) will be the number of infected mosquitoes which bite during the time unit, and also the number of persons (healthy or already infected) which are bitten by each. During the same time mosquitoes will become infected from \( n', \) \( n'' \) is the number of infected persons; and \( f' \) the number of those which are also infected to mosquitoes. Then \( f'2 \) will be the number of each which are bitten by mosquitoes during the time unit, and also the number of mosquitoes which bite them.

Let \( b \) and \( f \) be the proportions of persons and of mosquitoes in which the infection-event happens in a time unit, and \( p \) and \( f' \) the two populations. Some of these persons may possibly be naturally immune—that is, may not become infected although they may never have had the disease and remained from it. Let \( g \) and \( f' \) be the proportions (probably nearly unity) which are not naturally immune. Then \( bpg' \) and \( Nf' \) will be the respective numbers to which, whether they are healthy or not, the infection-event occurs in the unit of time. Hence:

\[ k' = \frac{bpg'}{Nf'}. \]

and since we wrote \( b = \frac{b}{b'} \) and \( f = \frac{f}{f'} \), we have

\[ k = \frac{b}{b'} = \frac{f}{f'} = \frac{N}{N'} = \frac{N}{N}. \]

Substituting these in equation \( (12) \) we have:

\[ \frac{N}{N} \left\{ (1 - r)(1 + N')/f + (1 - r)Nf' \right\} = \frac{N}{N} \left\{ (1 + N)(1 + N')/f + (1 + N)Nf' \right\} \]

with a similar equation for \( j \), the disease among the mosquitoes. Note that also \( dp = pf' \). The above equation gives of course only the initial value of \( a \), in terms of all the elements concerned.

(12). The Malaysian Expedition—We require to calculate these elements as best we can; but this can be done in present only on very insufficient information, and when we little more than merely conjectural ground. The reader must be warned on this point; but he will see
also that small differences in the actual figures are of less importance than the form of the equations obtained.

(i).

DeatMate and Birthrate. As stated in Section 1 (i), we know little or nothing regarding the average length of life of Anopheles, even in captivity, and much less when free. If we adopt the conjecture there made, that only one-third survive for ten days (long enough to allow the plasmodia to develop in them), we can calculate the mortality rate for one day (and therefore for any given number of days) from the formula:

\[ \log (1 - m) = \log 1/3 \]

Thus for one day \( (1 - m) = 0.301030 \) and \( m = 0.698969 \); and for one minute \( (1 - m) = 0.301030 \) and \( m = 0.698969 \). Obviously, at this rate 1/36th of the Anopheles survive for 20 days and 1/27th for a month (30 days), and so on.

The birthrate presents similar difficulties, because the number of eggs laid by a female is no indication of the number which survive. But if we suppose that the mosquito population is remaining stationary we can obtain \( n \) from the formula:

\[ (1 + n) (1 - m)^n = \]

Thus for one day \( (1 + n) (1 - m) = n \). Thus for one day \( (1 + n) = 1.16125 \) and \( n = 0.16125 \); and for one minute \( (1 + n) = 1.0001016 \) and \( n = 0.0001016 \).

The immigration and emigration ratios can be calculated from similar formulae if we know the amount of the migration at the end of any definite period. For instance, if one third of the mosquitoes leave a given area by the end of ten days the rates per day or minute will of course be the same as the deathrate calculated above; and if the immigration and emigration are equal, the immigration rate will be the same as the birthrate calculated above. In section (9) it was shown that, ceteris paribus, the migration ratio into or out of an area will vary inversely as the radius of the area, and reference was made to the law of random scatter in (9); but unfortunately we possess no trustworthy observations on these subjects—which I cannot discuss here. We should observe that deaths and emigrations can be dealt with as ordinary happenings (the former not subject to recovery), and as such in (9) it was shown that, ceteris paribus, the migration ratio into or out of an area will vary inversely as the radius of the area, and reference was made to the law of random scatter in (9); but unfortunately we possess no trustworthy observations on these subjects—which I cannot discuss here. We should observe that deaths and emigrations can be dealt with as ordinary happenings (the former not subject to recovery), and as such in (9) it was shown that, ceteris paribus, the migration ratio into or out of an area will vary inversely as the radius of the area, and reference was made to the law of random scatter in (9); but unfortunately we possess no trustworthy observations on these subjects—which I cannot discuss here. 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ADDENDA

The active and passive bitings will number the same—each insect may be considered as biting only one and a different person in the time.

Take, therefore, one minute as the unit of time, and let \( b_1 \) and \( b_2 \) be respectively the number of persons and of mosquito bites during the minute; and let \( b \) and \( b' \) be the respective proportions of the two populations, \( p \) and \( p' \). Then

\[
b \cdot b' = b_1 \cdot b_2 = b_1 / b_2
\]

Now, if \( p \) and \( p' \) be the numbers of persons bitten and of mosquitoes biting giving the period \( t \) (in minutes), we can feed their values by any of the happening equations (with \( r = 0 \) of (2)). Thus putting \( b_1 \) for \( v \), and \( b_2 \) for \( v' \), we have

\[
b^{-1} = \left\{ \left( b_1 + b_2 \right)^2 \right\} b_1 b_2 \left( b_1 / b_2 \right)
\]

and other form suitable for numerical calculation; with the same

\[
b_2 = b_1 / b
\]

The simplest way to form concrete ideas is to assign a sense of values to the minute-happenings \( v \) and \( v' \) then to calculate \( b_1 \) and \( b_2 \) for one day (1440 minutes). Suppose \( b \) and \( b' \) are zero, zero, zero, and its succession; let not \( b \) and \( b' \) be too high in any one; and let this number remain constant that let \( b \) and \( b' \) be zero in the days.

The equations new contain only \( b_1 \), \( b_2 \), \( E \), and we have to calculate \( b_1 \) from the number of persons bitten (\( m_0 \)) and of mosquitoes biting (\( m_0 \)), during one whole day. With regard to the former we may omit \( v \) for simplicity. The human birthrate (say 25 per annum) will consist only of an annual or have in a minute, as maintained by the effect of (1), and it will have small effect on the calculation for a day. But the mosquito birthrate (bevis) will be much larger and may be much larger.

The results are as follows—

<table>
<thead>
<tr>
<th>Human Population, 1,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>per minute</td>
</tr>
<tr>
<td>sum at end of day</td>
</tr>
</tbody>
</table>

Mosquito Population, 1,000,000

<table>
<thead>
<tr>
<th>per minute</th>
<th>1:0</th>
<th>1:0</th>
<th>1:0</th>
<th>1:0</th>
<th>1:0</th>
<th>1:0</th>
</tr>
</thead>
<tbody>
<tr>
<td>sum at end of day</td>
<td>1:0</td>
<td>1:0</td>
<td>1:0</td>
<td>1:0</td>
<td>1:0</td>
<td>1:0</td>
</tr>
</tbody>
</table>

These figures are for a changing population provided that the total value of the population remains fixed (static); that is, the fact that
is unity does not imply that every element in \( v \) is zero. The difference between the two second rows is due entirely to the higher birthrate of the mosquitos, which gives a modulus less than unity. The value of this modulus for the mosquitos is given in the third row of the mosquito table, since the final value, when \( t \) is increased indefinitely, is \( B' = r'. \) The modulus for the human population is more nearly unity.

If we wish to ascertain how many of the original population have been bitten or fed in one day we changed the elements \( x, \langle x \rangle \), and retain only \( y \) (the mortality). That is, we have only to multiply the figures given in the human table by the factor \( (1-\omega^2) \). For mosquitos the value of this for one day is estimated in (3) above as \( 0.194966 \) and as \( 0.13 \) for ten days. Thus out of a million mosquitos biting at a rate of 100 per minute, and dying at the rate of 76.6 per minute, 120,016 will be the number of surviving fed ones at the end of the day (the total number of survivors will be 553,956).

Of course it will be understood that most of the fed mosquitos or bitten persons at the end of the day will have been fed or bitten more than once during the day. The most probable proportions of those fed or bitten once, twice, three, etc., can be ascertained from (8) above, and will be studied in (15) below. The proportion of those which have never been fed or bitten dwindles as \( t \) increases, but never reaches absolute zero; and if the modulus is not unity it always approaches, that is, \( (1-i)^n; (b+n) \) in value.

The tables may be taken as applying to any kind of feeding, and therefore to males as well as to female mosquitos. But if the definition is confined to feeding on warm-blooded animals, the above table will apply only to the females—which may be taken as numbering half the total mosquito population. If it is confined to feeding on men only, the value of \( r' \) will be less than the most general one.

The question now arises, What is the most likely value of \( b' \) for human bitings? We have absolutely no experimental data to guide us; but may suppose, as a working hypothesis, that only about 1/6 of the surviving females will have succeeded in feeding at the end of 24 hours. This proportion is given nearly exactly (vide table) by \( B' = 0.001 \), or 101,000,000 bites in a minute. The static value is \( B' = 0.5 \), or almost half the females in a static population; but in \( B' = 0.001 \), half the females always present are fed ones. Out of 1,000,000 female mosquitos, \( 1/12 \), or 83,333 should survive for one month; and at the
Since \( f = \frac{1}{p}, \quad b = \frac{1}{p - f} \), where \( p \) is the population of female Anophelines in one human being. Thus, if \( f = 10 \) and \( p = 1000 \), \( b = 100 \) but a minute. With these constants, out of 1000 female Anophelines and 1000 persons, 144 of the latter will have been bitten, and \( f\) of the former will have been bitten at the end of one day (2400 bites).

The total number of bites given in the day will be \( 144 \times f \). For \( p \) above. Thus the average number for the whole human population will be \( 144 \) which amounts to \( 144 \) with the standard value of \( f \) just suggested.

Of course, the value of \( f \) will be largely reduced if the people are mosquito nets or screens; or if the weather is cold; or if the species of mosquito is not very voracious as I have sometimes supposed.

From the equation \( f' = \frac{1}{p} \), we see that if \( f' \) and \( p \) remain constant, \( f' \) varies directly as \( f \); the number of the human population — to a certain extent, we should expect. Since we have supposed that a bite lasts for only one minute, each bite does not necessarily imply a complete feeding.

It is easy to calculate the total number of bites given during their lifetime by an original mosquito population subject only to deathrates. Let \( f' \) be the number of bites given during the 24th and 25th hour (which is a brief one) and if \( f = f' \), then the total number of bites given by \( p \) in their lifetime will be

\[
\text{total bites} = f' + f' + f' + \ldots + f' + f = \frac{f'}{1 - f}
\]

If \( f' = \frac{1}{200} \) and \( w = 1000 \), this becomes \( \frac{1000}{200} = 5 \).

(iii). The Infectivity Ratio. — Owing to the fact that the plasmodia requires 5-7 days under the most favorable circumstances to mature in the Anophelines, not all the bites given by infected persons will also be infective; and for similar reasons not all infected persons will be able to infect the mosquitoes which bite them. In (vi) above we took the 1200 and \( f \) to denote the infectivity ratios. The value of \( f \) may be estimated by several methods, but the following is probably the simplest.

Suppose that \( p \) is a large batch of Anophelines fed on an infective persons at the same time, and then liberate and allowed to die at the
NOTES

If we neglect the small quantities \( N' \) and \( r \) when bracketed with unity (as we may do for our present purpose), and put \( B = \frac{N'}{\rho} \) and \( C = \frac{r}{\rho} \), we obtain

\[
x = \frac{A - BC}{P - A + C},
\]

Here \( c \), the number of infected people, can have only positive values. It obviously becomes zero when \( A = BC \), and after that increases continually, if either \( A, B, C, \) or \( P \) increase, until it approaches \( p \).

The value of \( A \) when \( x = 0 \), that is, \( A = BC \), may be called its critical value, because it gives the maximum number of Anophelines per man which may be present without spreading malaria. With the constants suggested above \( BC = 1,000,000,001,530,796,374 \), and is largely influenced by the biting factor. Thus, when \( B = 0.000 \) mares per minute, which I inferred in (12, 32) was a probable but high standard, the critical value of Anophelines per man is 1530. But when \( B = 0.000 \) per minute, many more Anophelines, namely 6559, are required to reach the malaria-producing point.

In the second equation given above, the term \( \frac{r}{\rho} - C \) is small compared with the first term, if \( P \) is less than \( \rho x \), especially if \( x \) is not high. We may then write for rough computation \( A = \frac{P}{\rho} - BC \) and

\[
x/\rho = 1 - A.
\]

The latter is evidently the same function as the equation (2) of section 28 for static malaria; but we must observe that here \( A \) is the number of female Anophelines per man present at any one moment, and is not at all the same thing as \( x \) in section 28 and in Mr. Walton's article, which denotes the number of different Anophelines, male or female, per month.

I now give the number of Anophelines per man calculated for various malaria rates and for various biting factors, with the constants suggested above (taking \( r = \rho \) and \( x + N' = 1 \)).

\[
\begin{align*}
x & = 0.001, 0.0001, 0.00001, 0.000001; \\
A & = 0.0001, 0.00001, 0.000001, 0.0000001; \\
B & = 0.0001, 0.00001, 0.000001, 0.0000001; \\
P & = 1, 0.5, 0.25, 0.125; \\
\end{align*}
\]

(1) \( B = 0.001 \) per minute, (2) \( B = 0.0001 \) per minute, (3) \( B = 0.00001 \) per minute.
The great effect of the biting factor is very apparent. As stated in (127), this will vary with the species of Anopheline and certainly with temperature and humidity. I think that the dampness and darkness of dwellings may also affect it, though they may influence other mosquitoes, wind, etc., may diminish it.

The rapid rise of the Haalaric rate, in consequence even of a small rise of the Anopheline rate above the critical number, is again most apparent. Thus, whatever the biting factor may be, the effect of doubling the critical number will be, roughly, to increase the malaria rate from zero to half the total population. And yet I doubt much whether this doubling could be ever detected without the most careful study. When we add to this the great effect of the biting factor, we shall understand why the correlation between the numbers of mosquitoes and the amount of malaria has not always been immediately apparent.

These laws, I think, not second in importance to any law connected with our subject. They apply also to other mosquito diseases, and, I may point out, could not have been obtained at all except by pathological methods. They form the basis of the reduction of these diseases by the reduction of the alternative hosts, because they show that anopheles palla a large reduction of the former is likely to result from even a small reduction of the latter—certainly if the latter were originally not more than twice the critical number.

The recovery, or rather reversion, factor, \( r \), was not exactly defined in section 28, and with the necessary definition (e.g., above) seems to lose some of its value. On the other hand, the infectivity factors, \( f \) and \( f' \), are very important. The public health effect of quinine must be mainly exerted through \( f' \) in diminishing the infectivity by reducing the gametoids in man and \( f \) must be greatly influenced by the death rate of the insects as well as by their species. Thus the malaria would be diminished by increasing either the larvalis or diapause of the mosquitoes. It would, therefore, be still more diminished by increasing both together; and yet high simultaneous increase might save the
total mosquito population, \( A \), the same as before—another law, this may help to explain several phenomena.

It will now be advisable to compare briefly the value of \( A \) here with that of \( A \) found in section 8. The former consists of females found at any moment; the latter of different males and females during one month. The number of different individuals found during a month will be composed of the original population, \( A \), plus the births during the month—excluding the immigrants. That is, if the population remains fixed in number, it will be \( A + 43200np \), taking \( n \) to be birthrate (\( = \frac{a}{60000} \)) per minute.

Thus the different individuals will number \( (A + 43200np) \), or \( 3.9 \times 10^5 \) during the month, where \( p \) is the number found at any one moment. If \( p \) consists entirely of females we must multiply it by \( 2 \times 5.39 \) to obtain both males and females during the month—that is, by \( 10.78 \).

In section 8, about 40 different male and female Anophelines per month were taken as the critical number when the malaria rate is zero. This would therefore correspond in the table to a biting factor of a little more than \( 1 \times 10^{-6} \) per minute; and we must apply the same factor to the other figures in the column to reduce to the standard of section 28. (A very rough method of dealing with this problem is given in section 8(a), but I have no space for full treatment of it.)

14. Happenings of Infinitesimal Period.—In the above I have supposed the unit of time during which \( \delta \) individuals are affected by any happening to be a finite unit, such as a minute or a day—though we may make that unit as small as we please; and this is the most general way of treating the subject. But it will be advisable to add now some notes on the case in which the unit of time is taken as being infinitesimally small. This of course brings the subject under the Infinitesimal Calculus, and is useful because it enables us to consider continuous variation in the functions.

(1). Let \( \delta t \) be the infinitesimally small unit of time. Then the various elements will also be infinitesimally small, and may be written \( \delta A, \delta a, \delta d, \delta N, \delta e \), etc., and their products, being of the second order of smallness, may be neglected. We thus have:

\[
\begin{align*}
V = & \int \frac{(N-M+e)}{2} \, dt \\
V' = & \int \frac{(N-M-e)}{2} \, dt \\
\delta A = & A \, dt \\
(s = & \int \delta M - \int \delta e) \\
\int \delta N = & 0.32 \, \delta t
\end{align*}
\]
ADDENDA

\[
H = (r - M) t (t + N) dt
\]

\[
(t - H) f = (r + N) dt + \int (N - M + M - E) dt
\]

Then the fundamental equations of (6) above, namely

\[
s = \phi = H; \quad (r + N) t = (I - H) V,
\]

\[
\frac{\partial \phi}{\partial x} = \phi (I - H) V ;
\]

should now be written

\[
s = \phi = (r - M) t (t + N) dt,
\]

\[
\frac{\partial \phi}{\partial x} = (r + N) t (t + N) dt.
\]

That is,

\[
\frac{d \phi}{d t} = \phi + (I - H) V ;
\]

where \( P, Q, P', Q' \) are the coefficients. Differentiating and eliminating, we have

\[
\frac{d^2 \phi}{d t^2} = P \frac{d^2 \phi}{d t^2} + Q \frac{d \phi}{d t} + Q' \phi + Q \phi' + P' \phi + P \phi'.
\]

That is,

\[
\frac{d^2 \phi}{d t^2} = (P + Q) \phi' + (P' + Q') \phi
\]

with the same equation for \( \phi \). Putting, in the latter, \( x = 0 \), we obtain

for the auxiliary equation

\[
\frac{d^2 \phi}{d t^2} + P \frac{d \phi}{d t} + Q \phi = 0.
\]

Replacing \( P, Q, P', Q' \) by their original values and rearranging,

\[
\lambda^2 + (r + N) (I - H) V + (r + N) (I - H) V = 0.
\]

As in (1 b), the roots of this are rational if \( r + N = F + 1 \) and are then \( (r + N) \) and \( (r + N) - (r + N) \). Denoting these by \( X \) and \( Y \), we have

\[
\phi = X e^{x} + C e^{t}.
\]

The four constants are determined only by putting \( t = 0 \) in these and in their differential coefficients, and comparing with the original differential equations, since

\[
(4 + t + N) \phi + (r + N) \phi' = 0;
\]

\[
(4 + t + N) \phi + (r + N) \phi' = 0,
\]

which are the same as the equations of (1, 6), and may be written in the various forms there indicated.
(ii). If in the second equation (10) we put \( p - z \) for \( a \), we have
\[
\frac{dp}{dt} = h(p-z) + \left( \frac{V-I-r-\lambda}{a} \right) \tag{11}
\]
This is the small term in the equation (1) above. It is the total population, \( p \), may be a variable function of \( t \), but if we take it as remaining constant during the enquiry, we obtain an equation which is immediately integrable in the reciprocal form of \( \frac{dp}{dt} \). The integration gives, if \( V = V_0 - b - r - N \),
\[
\int \frac{dp}{p-z} = \int \frac{V_0 - b - r - N}{p-z} \tag{12}
\]
where \( V_0 \) is the value of \( \log(p, t+1) \) when \( t = 0 \). Hence
\[
\frac{V_0}{p-z} = \int \left( V_0 - b - r - N \right) \tag{13}
\]
If \( V = 0 \) this is the same as equation (10) just given, and furnishes the mean value of \( t \) when the happening coefficient, \( h \), is a constant.

(iii). In many infectious diseases, however, the infection rate, \( h \), is likely to vary directly as the number of infected persons present at a given moment. Suppose therefore that \( h = cS \), where \( c \) is some constant coefficient; then, if \( p \) is constant,
\[
\frac{dp}{dt} = c(\frac{p-z}{p}) \tag{14}
\]
Hence if \( Q = V-I-r-N \) (which is negative if \( V = I \)),
\[
\frac{p+Q}{\frac{Q}{p}} = \frac{V-I-r-N}{p-z} \tag{15}
\]
As \( p+Q \) must be positive, \( z \) reaches the limit \( \frac{cQ}{p} \) when \( t \) is indefinitely increased.

This case would include equation (1) of section 28, in which we supposed \( b = \beta \lambda p \) (where \( \lambda \) is now expressed by \( c \)), and if the constants are suitably taken the formula would represent the continuous change in the natural rate on the supposition that \( h \) does really equal \( \beta \). This was, however, only an approximation made for a simple statement of the subject.

(iv). A more correct determination of \( h \) for the metaxenous diseases must be made by the method given in (10) above. If \( z \)
ADDENDA

1. $i'$ and $z'$ are the numbers of affected individuals of the two kinds of hosts respectively, then we shall have the two following simultaneous equations to solve,

$$
\frac{di}{dt} = \varepsilon(i - z) + (r - i - Y)z \\
\frac{dz}{dt} = k(z - z) + (r - z - X)z
$$

The values of $i$ and $z$ become static when both $\frac{di}{dt}$ and $\frac{dz}{dt}$ become zero. In this case we shall have

$$
i = \frac{2r}{\varepsilon + k} \quad z = \frac{Xr}{\varepsilon + k}
$$

These are the same as the equations reached in (10) and (11). Hence the general solution is more complicated than that of the special static case, and cannot be dealt with here.

1.5. Repeated Bitillings of Insects.—The theory of repeated happenings given in subsection (8) may be usefully employed in several ways—as in the two following examples. According to that calculation, if $i$ is the proportion of a population, $p$, affected by any kind of happening in a very short unit of time, then the most probable proportions of individuals to which the happening has occurred no times, once, twice, thrice, in the period $t$ will be given by $p^i$, multiplied by the successive terms of the expansion of $e^i$, that is by $1, i, \frac{i^2}{2}, \frac{i^3}{3!}, \frac{i^4}{4!}, \ldots$. The numbers thus obtained depend on the value of $i$ and the period $t$, but we can estimate them very readily if we take $t$ such that $e^{-i} = 1$. In this case we have merely to multiply $p^i$ successively by $1, i, \frac{i^2}{2}, \frac{i^3}{3!}, \frac{i^4}{4!}, \ldots$, or, what is the same thing, divide each previous term successively by $1, 1, 2, 3, 4, \ldots$. Thus, since $e^{10} = 22026$, if $p = 0.003$, $n = 0.003000$, $n^2 = 0.003000^2$—which is the number of individuals to which the happening has not occurred at all during the period $t = 1$. The number of individuals to which the happening has occurred only once will be the same, as well as those to which the happening has occurred twice, and so on.

Suppose that in an original population of 1,000,000 mosquitoes.
one covered in feeding every minute. Then 8 \times (6 \times e^t) = 496.0 \times \text{per minute. Now take } t \text{ such that } t = \frac{1}{2}, \text{ that is, we take a period of 10,000 minutes (= 166\frac{2}{3} \text{ hours, or nearly one week}). Then, if all the insects survive for this period, the numbers fed } x \text{ times should be as follows:}

<table>
<thead>
<tr>
<th>Times fed</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>367,879</td>
</tr>
<tr>
<td>2</td>
<td>367,819</td>
</tr>
<tr>
<td>3</td>
<td>123,900</td>
</tr>
<tr>
<td>4</td>
<td>63,975</td>
</tr>
<tr>
<td>5</td>
<td>19,716</td>
</tr>
<tr>
<td>6</td>
<td>5,905</td>
</tr>
<tr>
<td>7</td>
<td>1,773</td>
</tr>
<tr>
<td>8</td>
<td>511</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

So that as many should have fed only once as not at all, and only one should have succeeded in feeding nine times.

If, however, we suppose that the insects are subject to their ordinary death-rate, then we must multiply each term by \((1 - e^{-m \times 10,000})/e^m\), where \(m\) is the mortality per minute. The result will give the proportion of survivors at the end of the week which have fed a time.

This, of course, refers to special feedings, such as those on man. Otherwise the mortality of the unfed insects would doubtless be much higher than that of the fed ones, and the proportions would have to be calculated from the general happening equations in the case where \(t\) does not equal \(t\).

Suppose that the feeding factor per minute is only \(0.001\). Then the same proportions would be reached in nearly ten weeks. To find the proportions at the end of one week we must divide \(e^{-t}\) or \(0.999827\) successively by 1, 10, 20, 30, ... Thus only 0.999814 of the insects will now have fed once, and 0.00024 twice.

It is convenient to use the same \textit{standard periods} for the values of \(t\) which make \(e^{-t}=1\) or \(e^{m}=e^{-t}\), where \(t\) is any number employed in these calculations—we (17) below.

If the feeding factor is \(0.001\) per minute, 1,000,000 mosquitoes will have 1,000,000 feeds in the standard period—if they all survive; that is, an average of one each. But only 1,014,281 will have fed at all; so that on the average each of these will have had 1.014 feeds in the week.

(16). Repeated Infections.—Obviously in any malarious place a number of persons will be infected over and over again; though, if they are already infected they will not be able to recognise when such reinfections occur. The theory of repeated happenings enables us to calculate by precisely the same method just used how many persons
From this we can calculate \( b \), and therefore also the standard period, \( t = \frac{1}{h} \). Then in that period the number of persons infected no times, once, twice, etc., will be the same as those just given for repeated feedings during a standard period.

For example, let half the people be infected, so that \( 1 = \frac{1}{2} \). Let \( r = \frac{\text{births per minute}}{\text{people per minute}} \) as in (15) above, and let \( \lambda \), the laceration per minute, be \( \frac{100000 \times 0.005}{75} \). This \( \lambda = \frac{100000 \times 0.005}{75} \) per minute, and the standard period is \( \frac{1}{h} = 185710 \) minutes, or \( 29 \) days. Hence, during this period, out of 1000 people, 368 will not receive any infection, and 368, 184, 61, 15, and 3 will have been infected respectively. The total number receiving infection during the 129 days will be 632, and each of these will have been infected 2.582 times on the average.

This may appear inconsistent with our assumption that the static malaria rate was one-half, or one out of the 1000 people—because here we find that no less than 632 persons have been infected in a little over four months. But we must remember that the reversion rate is calculated on the basis that half the sick revert every three months. In the face of this reversion rate, the infection rate must be very high to maintain the malaria rate at such a figure as one-half.

If the malaria rate is only one-quarter, we should have \( \lambda / 4 \) instead of \( \lambda \). Hence the standard period would be three times as large, namely 54 days (provided that the malaria constants remain unchanged during all the period). But at the end of this larger period the number of persons infected no times, once, twice, etc., would be the same. If the malaria rate is one-tenth of the population, the standard period would be nine times larger than when it is one-half—that is, it would be 166 days. During one-twelfth of this period, namely 13 days, 907 people out of the thousand would remain unaffected—about 9\%.

(17) Some Values of \( e^x \) and \( e^{-x} \).—Readers who may wish to follow these calculations but who possess no book of logarithms may like to have a simple table for dealing with the exponential functions of time used in this section. Of course if \( x \) is not greater than unity, and especially if it is much smaller, we can easily obtain approxi...
from the expansion \( e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots \) (if \( x \) is negative the second, fourth, sixth terms in the expansion will also be negative). But we can often follow the simple course of taking such that \( x \) has one of the values given in the following table:

<table>
<thead>
<tr>
<th>( x )</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 0.6 )</td>
<td>1.82115</td>
</tr>
<tr>
<td>( 0.7 )</td>
<td>1.90837</td>
</tr>
<tr>
<td>( 0.8 )</td>
<td>2.01818</td>
</tr>
<tr>
<td>( 0.9 )</td>
<td>2.14593</td>
</tr>
<tr>
<td>( 1.0 )</td>
<td>2.27828</td>
</tr>
</tbody>
</table>

The subject is capable of elaborate examination; but it will suffice to use here the simple process employed in (17, iii) for determining the infectivity ratio of Anopheles \( \text{malariae} \). We can ascertain the total number of days (or other units of time) lived by an affected population, and also the number of days lived during the episode under study, we can then obtain the ratio of the latter to the former, and the
ADDENDA

ratio of the number of individuals "in episode" to the total number affected will be the same.

The number of days lived by a population during a given period is evidently the product of the number of days during the period and the sum of the varying or constant population living on each day; if there are 1,000 individuals alive on each day, 10,000 days will have been lived in 10 days. Now let \( p_0 \) be an original population, all of whom have been infected at the same moment and are thereafter subjected to the usual revision and mortality rates. Then if \( p_1, p_2, \ldots, p_t \) be the numbers of those living at the end of the first, second, \ldots, \( t \)th day, the number of days lived by them up to \( t \) will be \( p_1 + p_2 + \ldots + p_t \).

The value of \( p_t \) for \( t \) is given in (1, \( n \)) above, and \( n = (1 - r) - (1 - M) \) if we span only these elements; and the sum of \( p_1 + p_2 + \ldots \) is found by integrating this function. If \( r \) and \( M \) are small the general integral may be written in the exponential form \( \sum_{i=0}^{\infty} \frac{(1 - r - M)^i}{i!} \), or, in the exponential form, \( e^{-(1 - r - M)} \).

Here, if we wish to obtain the sum of the populations between the two periods \( t_1 \) and \( t_2 \), we have:

\[
\sum_{i=0}^{t_2} \frac{(1 - r - M)^i}{i!} (1 - r - M)^{t_1 - i} = \sum_{i=0}^{t_2} \frac{(1 - r - M)^i}{i!} (1 - r - M)^{t_1 - i} \cdot \ldots \cdot (1 - r - M)^{t_2 - i}.
\]

And these give the number of days lived between \( t_1 \) and \( t_2 \). If \( t_1 = 0 \) and \( t_2 = \infty \), both expressions become \( \int_{t_1}^{t_2} \frac{(1 - r - M)^i}{i!} \), so that this gives the total number of days lived by the whole affected population \( p_0 \) while they remain affected and recover. Otherwise, if \( t_1 \) is the date of the beginning of an episode and \( t_2 \) that of the end of it, the definite integral will give the number of days lived by the population while they are passing through the episode—that is, while they are infected, infective, or sick. And the ratio of this number to the total affected days gives the proportion of episode-days to affected-days. Finally we infer that in a general population of individuals infected on different days the proportion of episode persons to total affected persons will be the same; that is, will be \( 1 - r - M \) or \( 1 - r - M \) if both affective days are included, respectively. If \( t_1 = 0 \) and \( t_2 = \infty \), or \( t_1 = 0 \) and \( t_2 = \infty \) if both affective days are included, respectively. Approximately.
For example, suppose that we wish to know the probable proportion of persons affected with malaria who are also in the acute stage of fever which, say, lasts from the fifteenth to the thirtieth day after inoculation. Taking \( r = 0.07672 \text{ per diem} \) and \( M = 0.0000675 \text{ per diem} \) (which is a low figure for malaria), we have \( 0.024349 \text{ per annum} \), a low figure for malaria. That is, the persons with acute primary fever about one-twelfth of the total affected persons.

The average number of affected days lived by a person in the case of malaria with the constants used above would be 179, or nearly the same as the standard period obtained in \( e \) above for the case when \( n = 0.0000675 \text{ per diem} \). This is because the birth and death-rates are taken as equal.

But the malarial death-rate is probably considerably higher and the affected days lived \( 1/(r+M) \) lower.

Of course, in the applications to various diseases, the constants must be separately calculated, and we assume several very poor cases of the work. The mortality presents this difficulty, that is not constant but generally much higher during the acute stage of the affected race. We then proceed as follows. We first divide the whole affected period into three, the incubation period, the acute period, and the subsequent period. For the first and third we suppose that the ordinary death-rate, \( n \), holds, and for the second period, the morbid death-rate, \( M \); and we then calculate separately the total affected-days and the episode-days by means of the formula. But the rate is which determined by the length of the episode-period in comparison to the total affected-period.

By putting \( r = n \), \( M = 0 \), and \( h = \infty \) we find the total average number of days lived by the whole population, with the given death-rate. Thus with the rate used above it amounts to nearly 40.9 years.

Conclusion—It cannot supply in time for the present edition of this book any fully worked-out example of the applications of the theorem to diseases other than malaria—but such applications are numerous and important. For example, it has recently been observed that sleeping sickness is almost entirely in the Gambia hinterland, giving a value of \( z \) less than 1%. And it has been suggested that this may be due to racial immunity of the people, that is, to a low factor, \( g \), in equation \( (a) \). But another sufficient explanation might be simply that the Glossina palpalis is not numerous enough over and above the critical point to cause more widespread disease. This is likely to be the case because, I hear, \( z \) is highest \( 15 \) to \( 30 \) miles from the coast.
Other hypothesis, $\gamma$ and $x$ should be lowest. Another important case is that of yellow fever. When the disease was shown to be carried by mosquitoes, it was at once assumed to have a very low endemicity similar to those of malaria, namely that the entire human population were the reservoirs of the infective organism, though they had acquired immunity to its effects. But a study of equation (ad) shows that this cannot be the case, if certain classical observations are sound. Immunity is so lasting in this disease that $\gamma$ may be put almost at zero, so that the affected days continue almost to the average life of the population. On the other hand, good experiments have shown that the human host is infective for only about three days. That is, the ratio of infective to affected days is extremely small, so that the factor $\gamma$ of equation (ad) is also extremely small. Moreover, so far as we can judge by the loss of infectivity and illness the infected days are also very few—under a week or so. On the other hand, $S$ almost lives for months and remains infective all the time; so that its infectivity factor $\beta$ and also its infected ratio are very high. From these data it is clear that yellow fever must be of very low endemicity in man (endemicity = the infected ratio), and of very high endemicity in the mosquito. In other words, the mosquito and not the man are the "reservoirs" of the infection. It has also been assumed that where the disease flutters, this is because the human $x$ is high—because all the natives have acquired immunity and only new-comes are infected, but a low Stegomyia factor will easily explain the same thing. Much has been written regarding the absence or presence of yellow fever in the Old World. The disease is certainly absent in many countries where $S$ almost exists. But Mr F. V. Theobald informs me that, so far as his study of large collections, this insect appears to be much more rare in the Old World than in the New; and this, if correct, might be a quite sufficient explanation of the whole phenomenon.

The venereal diseases may be looked upon as sex-transmitted diseases in which the two sexes take the part of the two hosts. Thus the constants of the two groups will be the same, and $\gamma = \gamma'$, so that the disease comes under the case of equation (ad).

The reader should examine as an exercise the equations for the number of infected Anophelines in India. It will be seen that the so-called 'independent production' of affected mosquitoes to each man, and that the
malaria rate among the insects is always much lower among the reefs than among the human population. Even if all the latter are affected and if the biting factor is as high as 0.0001, only about one-fifth of the female Anophelines will be infected ones (the other constants being assumed correct).

The important phenomenon of what may be called "smouldering disease" occurs when $f$ remains just at the critical point; and the reader should consider carefully the conditions connected with it.
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