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GENETIC COMPOSITION OF COLOUR PATTERN OF DANGI CATTLE

INTRODUCTION

"Colour forms the trade mark of the breed" says Gilmore (13). It has an advertising value. It is associated with utility and possesses an advantage in courtship and as protective colouration.

According to Gilmore (13) colour has a great importance as it constitutes a check on the authenticity of registration. The colour pattern forms the bases of understanding how inheritance behaves and its value of utility is associated with certain colour characters. Fads for colour patterns exist among some of the breeders having high records made by certain of their cows with particular colour pattern. Colour patterns have, however, not been associated with the productive ability (13). Colour characters and responsible genes lend themselves to one of the best analysis of inheritance. Colour has direct or indirect effect upon well being of animal.

According to Gilmore (13) all cattle are 1) Coloured (C) and 2) Albino (cc). Two basic colour in cattle are red and black. In formation, red is produced before black. Red is considered by Ibsen (17) to be dominant homozygous in all pigmented cattle. For colour to form, both chromogenes (precursors of colour) and several enzymes
must be present and react. The colouration pattern is laid down during fetal life with body extremities being affected first (13). Esskuchen (1930) quoted by Gilmore (13), detected by means of a "dopa" reaction the pigmentation components in a fetus of one month old. In dark breeds, colour is apparent on muzzle at 3 to 4 months and pigmentation spreads over the body by 3½ months and complete as to its intensity by 7th month of fetal age.

The relation of this study to utility is a further problem for investigation. It is said vigour is generally associated with the shade-colour, according to some cattlemen. But scientific findings absolutely lack to correlate and support this statement (13). As the colour has direct or indirect effect upon the well being of animal, its inheritance is of a great value to the live stock owners. White cattle can withstand sun-heat very well, black cattle do not as black coat colour absorbs the sun-heat. Such animals are relatively in discomfort to work or graze in the hot sun.

Some colour genes are linked with the other genes like those responsible for fertility, e.g. gene "N" (roan) is linked up with a recessive gene for infertility from abnormal development of the Mullerian duct (13). Comfort A (8) correlates coat colour and longevity in thorough bred mares. Dowling D.F. (9, 10) states that
the body coat is associated with heat tolerance in cattle. Schaefer H (26) has confirmed that a recessive lethal or semilethal factor linked with the white factor resulted in the mortality of homozygous grey lambs of Karakuls in Germany. Turner H.G. and Scheleger A.V. (31) have carried out observations on associations between coat type and performance in cattle. White S (34) has revealed the association of the factors "Shivering Si" and "diminution dm" of silver-white coat colour of Guinea pig with higher mortality in the litter and Male and Femals sterility.

Further the effect of internal environment on the expression of genes is ideally demonstrated by the reversal of dominance exhibited in traits influenced or modified by relative levels of the sex hormones (3). The concept of "sex influenced inheritance" is but vaguely understood. The better and appropriate term is "sex influenced" instead of "sex controlled", "sex limited" or "sex modified" (3).

The colour Mohogany described by Wentworth (32, 33) or the present equivalent of it, "Blackish pattern" described by Gilmore, Baldwin et al (3) is the best example of sex influenced colour character in Ayrshire and Jerseys.

Deakin (1944) quoted by Gilmore (13) assumes that whole of the colour pattern is governed by delicate balance between the sets of processes regulating pigment formation and inhibition of pigment formation.
It is worth noting here that extensive work has been done on 'Inheritance of Colour' in horses, cattle, sheep, pigs, mink, rabbits, Guinea pigs and mice (24).

For the study of Genetic make up of colour pattern" it is desirable to know the skin structure, hair structure and the melanin formation (13, 22, 27).

The skin of the animals is so made and strategically placed to help protect the animal in varying surrounding. General microscopic picture is more or less the same in all animals. Skin consists of two layers that are different in character and derived from the different germ layers:

I. Epidermis is an outermost and thinner epithelial tissue derived from the ectoderm. Epidermis has five layers or strata, within without (13).

1. Stratum germinativum or basal cell layer. This is the deepest layer of columnar cells.

2. Stratum Granulosum: Several cells thick - polyhydral cells with fibrils.

3. Stratum granulosum: diamond shaped cells - it is here the epithetical cells die.

4. Stratum lucidum: very thin and appears as a clear, bright homogenous line.

5. Stratum corneum: outermost layer of horny cells.

II. Dermis is the innermost and thicker, derived from the ectoderm.

Hair follicles start developing in early 3rd month
of total life from the epidermis (13). The fetus at about 6th month becomes covered with delicate hairs called "lanugo" (wool) which shed before birth and replaced by new one. In cattle, it is shown that the hair follicles undergo two resting and two active phases in a year (11).

The hair follicle is an epithelial structure much like a gland which proliferating into hair structure. The central cells develop into "medulla" of the hair shaft which consists of loosely connected soft but horny cells with air spaces. Next concentric structure of matrix develops into the "cortex" the main constituent of hair shaft. The horny cells of cortex are hard and lightly woven - which carry much of the pigment of hair. Outermost layer consists of the hardest horny cells - "cuticle of the hair". The colour of the hair depends upon the quantity and quality of pigment present in the cortex. If there is no pigment in the cortex the hair appears white even though it has dark medulla. The pigment is called "melanin".

Melanin (27) is the endogenous group of pigments which gives colour to the skin and hair and to the iris and provides the black reflection - proof inner coating of eyeball. Complete chemistry of melanin is not known. It is considered to be formed from the amino acid tyrosine which differs from phenylalanine (beta phenyl, alpha amino propionic acid) by having one hydroxy group attached to
the phenyl group which therefore also called as "hydroxyphenylalamine". (27).

It is likely that there are many melanins. They are widely distributed in animal kingdom and range from yellow through brown to black in colour. Red and Black melanin pigments are easily distinguishable (1). A "chocolate" melain (7) exists in G. pigs and is chemically identical with black melanin (1). Melanin and its amount in the epidermis is responsible for the difference in colour of the skins of those of different races (black, brown, yellow and white). All possess melanin in their skins. An inherent tendency of inability in any individual of any face to produce melanin pigment results in an "albino" (albus = white) (13).

In the animals and human beings melanin occurs in the form of fine rounded granules brown to black, in the cytoplasm of the epithetical cells chiefly in the basal layer of the epidermis. Hairs partake the same pigmentation to the degree some what proportional to that of skin (27). It is noticed that bay, brown and even sorrel horses have black skin as do red and fawn cattle and swine. In some breeds of cattle especially Jerseys and some dog breeds e.g. chow the m.m. of mouth shares the pigmentation of the adjacent skin (20). The same is true of hoofs. White hoof is a tissue growing from white skin and this is largely true of horns. Melanin gives colour to iris and thick
black zone of it in the layer of cells where the retina joins the choroid totally blackens the interior of the uveal space.

All the cells which contain melanin do not necessarily manufacture them but some cells merely phagocytose the melanin granules. These cells of epidermis, that phagocytose melanin are of the order of macrophages and are called "Chromatophores" (phoro = 1 carry) (13). The cells which are actively engaged in the manufacturing of melanin are called "Melanoblasts". These are specialized cells beneath the epithelium which possess long dendritic processes inter-spread among the epithetical cells. The melanoblast is a specialized cell of the basal layer of epidermis which is responsible for the production of melanin. The bulk of it is clearly located in the basal and adjoining layers of epidermis. The Melanoblasts - the melanin forming cells are easily differentiated from the chromatophores or melanophages - cells which merely phagocytose melanin. The test used for this purpose is "dopa reaction" developed by Bloch (16). Fresh frozen sections (or paraffin sections if special precautions are taken) of tissue where in the enzymes of melanoblasts remain active, are incubated in a "dopa". The enzymes will act on the "dopa" and convert it to the pigment which will darken the cells. Bloch refers to the enzyme contained by the melanoblasts as "dopa oxidase" and material formed by the interaction of "dopa" and "dopa oxidase" as
"dopa melanin".

In the hairs the melanin is in their cortical substance derived from the epithelium of hair follicle. Gross appearance of colour of skin or hair appears to depend on the concentration of melanin granules and upon their molecular structure (27).

In animal kingdom, melanin serves as protecting colouring. In man - a protection from sun light. Melanin is considered of prime importance in protecting the tissues from "sun burns" (13, 27).
Ibsen (17) was the first to give a detailed account of colour genes in cattle. In a classical paper on "Cattle Inheritance I Colour" Ibsen (17) described colour genes occupying 19 different loci. He described each gene with its action and designated it by means of distinctive letter. The symbols, effects and interaction of these genes formed the bases of future work on the cattle colour-inheritance. Staffe (1925) in Germany quoted by Klesish and Horst (19) published original work on "Colour Inheritance in Cattle" which is in good general agreement with that of Ibsen (17).

A year later Ralph Boart and Herman L. Ibsen (7) began a systematic study of hair and skin pigmentation in cattle. The object of this study was to determine the effect of genes postulated by Ibsen (17), on pigments of skin and hair. In this study Bogart and Ibsen (7) used the symbols and gene description designated by Ibsen (17).

**GENE RED : R**

The gene red "R" is present in all pigmented cattle but it is not always expressed being hypostatic to many other genes (17). It is always found in homozygous condition and consequently has no allele. It causes hairs to be red and when not affected by other genes, is responsible for brownish pigment in the skin
of nose and eyelids.

**GENE BLACK : B**

Black "B" gene is responsible for the black pigmentation in the hair, skin, muzzle, hoofs, tongue, lining of mouth, eyelids, nictitating membranes and white of the eyes provided the white spotting gene "s" does not interfere. It has no allele and its absence is "b" (17).

**GENE : BLACK SPOTTING OR BLACKISH PATTERN : Bs.**

"Bs" gene like "B" gene causes black pigment to appear in skin, nose, hoofs, tongue, lining of mouth, eyelids and white of the eyes if the animal is a self (S). "Bs" is not fully expressed in newly born calf. Black pigment gradually creeps in with the increasing age and males as a rule develop more black than the females. There is sex limited tendency. All that can be said about recessive gene "bs" is that it is the absence of "Bs". Since "B" and "Bs" both produce black hair in one or other form and since "R" is always present - "bb bsbs" animal would be always red and devoid of black pigment in hoofs, nose, tongue, lining of mouth, eyelids and white of eyes provided animal does not carry gene "Ps" for pigmented black skin spots.

Pearl (1913) and Hooper (1921) quoted by Ibsen (17) postulated a separate dominant gene for black tongue in
Jerseys. But black tongue in Jerseys is due to "Bs" factor associated with gene 'S' and not due to separate factor. Important cause of light tongue in few Jerseys is due to white spotting gene (s) which brings lack of pigmentation in the tongue as well as in other parts of body (17).

**BLACK SPOTTING MODIFIERS : M AND L**

According to Wentworth (32, 33) quoted by Ibsen (17) the sex limited effect of "Bs" is due to allelomorphic genes "M" much black and "L" little black. "M" is dominant in males and recessive in females, while "L" is dominant in females and recessive in males.

**BRINDLE : Br; MODIFIER OF Bs**

Brindle usually does not appear in any of the pure breeds but is found in Scrubs (17). It is expressed as irregular narrow stripes of black hair on the red background. The character Brindle is due to the joint action of two genes "Bs" and "Br". "Br" has no effect on "B" animals, since "B" is epistatic to "Br" and none in "bb bsbs" animals since there is no black present. Cole (1925), quoted by Ibsen (17), reports that Brindle may be carried in full blacks (Angus) or in clear reds (Red Danish).
INTENSITY AND DILUTION FACTORS: I. ii D. d

There is enough evidence that in cattle there is a form of dilution due to a dominant gene "D" and also due to a recessive gene "i". Dominant D has its effect on black "b" changing its expression to dun and recessive "i" has its effect on "Bs" expressing it in lighter shades of red (17).

SELF; S AND RECESSIVE WHITE SPOTTING: a

A self animal is entirely pigmented and therefore shows no white spotting. The gene for self "S" is allelomorphic with "s" the gene for recessive white spotting. But according to Cole (1924) quoted by Ibsen (17), supposedly "S" is not completely dominant to "s". The gene "S" is quite variable in its expression due to modifying factors and therefore non germinal in nature i.e. white spotting on the two sides of animal are generally unlike. "S" is not only responsible for white area in the coat but also responsible for white areas in the tongue, nose, lining of mouth, eyelids, nictitating membranes and white of eyes. This is only when animal carries "b" or "Bs".

MODIFIERS OF s: Lw and Lw and Pl and pl:

Great deal of work has been done by Ibsen (18) on the modifiers of "s". Single pair of modifiers is
responsible for the varying amounts of white in Holsteins (Lanpact 1926, Dunn, Webb and Schneider 1923). These genes are entirely quantitative in their action. Factor causing small amount of white "Lw" is incompletely dominant to its allelomorph "lw". Guernseys and shorthorns invariably have small amount of white spotting (Lw Lw) and seem to breed true without selection. Many Ayreshires are almost entirely white, "lw lw".

"Pl" - another modifier of "s" : Animals carrying "Pl" are pigmented to a large extent below the knees. In pigmented animals (Pl) the pigmentation seems to be cencentrated around the hoofs and extend upwards. The gene "Pl" either in homozygous or heterogygous condition is found in Ayrshire Holstein and Guernseys, therefore these breeds are pigmented legged. Others are "pl pl" and therefore they are expected entirely white from knee to the hoof (17).

According to Frankquist and Bowman (1923) there are three pairs of genes affecting the amount of white on heads in Holsteins, and in red and white Swedish breed. There is close correlation between the amount of white spotting on the region of body and amount of white on head (17, 28, 29, 30). Animals with "Lw Lw" have less white on head than the animals with "lw lw".
Occasionally pure white or almost pure white animals are found in Ayrshire and Holsteins. Such animals are "ss lwlw".

Hooper (1921) quoted by Ibsen (17) assumes that there is a separate gene for white switch in Jerseys. The analysis of data shows white switch was found mostly in animals that carried white spotting "s s" in other parts of the body. A few so called selfs also have white switches. Author's (17) observations are, if animals carry any white at all, the tail end is one of the places almost invariably affected. This has same fact which applies to the effect of "s" on the pigmentation of tongue, animals with "ss" invariably have unpigmented tongue (17).

GENE ROAN : N

The completely dominant factor "N" which causes hair of any colour to become devoid of pigment and therefore white (17). In heterozygote condition "Nn", an individual becomes roan, while in homozygous condition "NN" nearly all the hairs except some in the ears are white.

ROAN MODIFIER : rm

A bull roan when young changed to red gradually (Smith 1925). This is due to recessive modifier "rm".
Interaction of "N" with other genes; when white short-horns (bb bbs NN) mated with Jersey (bb BaBs nn), the offspring (bb BaBs Nn) should be blue grey in spots and red roan in remainder of body (Ibsen 1933).

RECESSIVE WHITE : wn

According to Manresa, Gonzabz, Sarao and Esquerra (1930) quoted by Ibsen (17) Nellores in India are phenotypically white but indications are that they are grey (25). White animals have unpigmented skin. Nellores have deeply pigmented skin i.e. almost black. They called Nellores as "Silver grey". Silver grey of Nellores is a form of recessive white "wn", "n" standing for Nellore. Several explanations for black skin in Nellores are put forth, that it is due to separate factor, that "wn" is completely epistatic to "Bs" and"B". "Wn" gene when in homozygous conditions prevents the formation of pigmentation in hair but have no effect on skin (17).

Wenthworth quoted by Insen (17) shortly after 1st world war found that macroscopically "wn" hairs did not seem pure white and under microscope they showed black and red pigment granules sparsely scattered throughout the hair. So it seems "wn" gene causes extreme dilution. The presence of black and red pigment indicates that the animals are "bb" and at the same time "Bs".
DOMINANT WHITE : Wp

The white English Park Cattle carry a factor for
dominant white "Wp". It seems this factor causing white
park animals largely white is actually a form of dominant
white spotting. In white Park Cattle, both non whites
and self (Black) are produced. "Wp" is incompletely
epistatic to self "S". An absence of "Wp" is "wp".

DOMINANT WHITE SPOTTING : SH, SD and SC

SH : "H" being used to designate the white spotting.
"H" plays important part in producing of whole
herford coat pattern. "H" is epistatic to "S" and "s". "SH" has modifiers, "lw", "lw" for
little white and more white respectively.
"Rn, rn" Red necked and its absence; "Re" for
red hairs around eyes and its absence "re"
(Pitt 1926).

SD : Dutch belt. Animals are black and white. White
restricted to the belt only. "D" is dominant
to "S" and "s" (18) "DSH" heterozygote animal
expresses both patterns and thus are allelom-
orphic.

SC : Originated by Wriedt (1925) quoted by Ibsen (17).
These factor "SC" causes the animal pigmented
on both sides with remainder of body white. "C"
is incompletely dominant to "S" and completely
to "s" (17).

The genes "SH" Herford pattern, "SD" dutch belted, "S" colour sided, "S" and "s" recessive white spotting form the allelic series. The genes "SH", "SD", "S" and "s" are incompletely dominant over each other. But all of them are completely dominant over "s" (4, 5, 18).

INGUINAL WHITE : In

"In" is responsible for the dominant inguinal white spotting and is not allelicomorphic white "S" and "s" as the hairs and skin of these spots are devoid of pigment (7), "ss" animals carry "In". Inguinal white factor "In" is dominant to its allelic form "in" which is merely the absence of dominant "In". "In" is epistatic to "S". Animals with "ss InIn" are usually white along entire underline (17).

WHITENING : W

Jersey breed is very often described as "Fawn". Besides the black spotting "Bs" and some forms of dilution factors (either i or D), there is also another factor which produces here given name, "whitening". White muzzle surrounds the black nose. The factor is recessive and designated "w" and also causes the hairs inside the ears white and also responsible for hairs on belly white and
on under white. The allelomorph of "w", which is dominant "w" prevents the expression of this character (17).

**PIGMENTED (BLACK) SKIN SPOTTING : Ps**

The combination of either "b" or "Bs" with "s" generally results in an animal with black as well as white coat spots on body; and also black and white spots on the nose, tongue and lining of mouth. According to miss Pitt (1920) quoted by Ibsen (17) there is dominant factor for pigmented nose. The dominant factor "Ps" for black pigmented skin spots, may fall anywhere on the body. The animals of composition "paps" would have no black skin spots. "Ps" is responsible for the Pigmented (black) skin spots to occur on otherwise brown skin areas (15).

**RED HAIRS;**

Under microscope, typical red hair differs from blackish hair only in amount of black pigment. The shade of red hair is due to two distinct causes: 1) The shade of red pigment itself and 2) The amount of distribution of the black clumps (7). The variations in kinds and amount of pigment in the hair accounts for many intergradations found in red hairs. Proximal ends of red hairs being more dilute than distal. The nose skin of red animals is brownish in appearance. It is
found to contain both red and black pigment.

BLACK HAIRS

Whole mounts of black hairs "R" from either Angus or Holstein appear solid black even under high magnification i.e. cortex and medulla are not demarcable. The presence of red pigment in black (B) hair is revealed by bleaching the black clumps by $\text{H}_2\text{O}_2$. (7). Generally 48 hours or more are required to complete the bleaching of black and about two weeks are required for bleaching of red pigment (7). Bleaching of black pigment reveals the red pigment in black hair. Confirming Ibsen's (17) statement that red "R" is always present in all pigmented cattle. Nose skin of black "R" animals contain less black pigment than do the black hairs. The pigment is found in all animals in epithelial cells of skin in the form of crescent shaped clumps. These are in cytoplasm near nucleus, nearest surface of the skin.

BLAKISH HAIRS

Jersey and Ayrshire cayy the gene "Bs" which causes the hairs a more or less blackish in appearance. In Ayrshire the colour is often termed as "mahogany" (32, 33). In Jerseys, the combined action of several (genes) modifiers e.g. "whitening" (w) and "tipping" together with dilutors of red and the "Bs" gene produce the "fawn"
colour. Many of "B's" hairs are "fawn"; and therefore blackish only at the base and yellow or cream at the tip.

Blackish "B's" hairs have usually reddish tint; but may look quite black on the animal. The whole mounts look even more reddish. The diffuse transparent red pigment is much more noticeable in the cortex than in the medulla (7). Hairs of "B's" animals differ considerably in their degree of blackishness. It is entirely due to the amount of black clumping in the cortex. All "B's" hairs examined microscopically show some red in the whole mounts but typical "B" hair under similar conditions look completely black. This is better way of distinguishing "B" hairs from "B's" hairs. Thus microscopic method helps to distinguish the black hairs due to "B", from those that are due to gene combination from which "+B" is absent (7).

Bleaching with \( \text{H}_2\text{O}_2 \) causes the black pigment to become colourless in "Ba" hairs as it does in those from a "B" animals.

"B's" gene not only causes red hairs to be blackish but also is responsible for the presence of black pigment in the skin. This is apparent in the skin of nose. The chief difference in "B" animals is that the black pigment is more plentiful in the surface cells of nose, giving more blackish appearance. A close correlation exists
between the amount of black pigment in the hair of a "Ps" animals and the amount of black pigment in the nose.

**WHITE HAIRS**

These are four kinds of white hairs:

1. White hairs from animals e.g. Ayrshire carrying recessive gene for white spotting (s).
2. White hairs from Herefords "S^H".
3. White hairs from shorthorns "NN".
4. White hairs from so called "Albinos" "cc" (13).

Of large number of white hairs examined only few are devoid of pigment. The remainder have varying amount of black clumping in the medulla. no red pigment is found in the white hairs and if at all any, in the proximal end only. If the animal is carrying "R", apparently it has some effect on the amount and distribution of the black pigment in the cortex of hair. In "R" animal the black pigment extends throughout the length of cortex of hair. But in recessive white spotted animals (BsBs ee ss) the black pigment, in the cortex is rare and if any, only at the tips (7). The white hairs e.g. "S^H S^H bb" and "NN bb" are quite similar to each other and similar to white hairs from "ss" breeds that do not carry black "B". In all of them the black pigment when found in the cortex is located only at the tips of the hairs. Thus depending upon
whether or not an animal carries "b" or "s", there may or may not be black pigment clumps throughout the length of the cortex of certain white hairs. Of hundreds of white hairs examined as well as pigmented white hairs examined, no single case has been found of a hair having black pigment in the cortex and no black pigment in the medulla. The reverse is however quite common (1).

Minnesota albinos are almost pure white in appearance and have pinkish eyes. The iris however is white. Approximately half of the hairs examined from these animals, are entirely devoid of pigment, while remainder have black pigment in the medulla. The white of "albino" correspond to the white areas of a typical black and white (ss) animal. According to Carstens et al (1934) quoted by Dsend and Bogart (17) in true "albinos" of Allarauer breed of Germany, the hairs as well as the skin and eyes are entirely devoid of pigment.

When black B hair is bleached the red pigment becomes visible but when black pigment in the white hair is bleached no red pigment is revealed (17).

Pigmentation of "white" nose skin of a recessive white spotted animal (s) and "sh" animal, showed that black pigment is found only in the form of small scattered granules.
PIGMENTED (BLACK) SKIN SPOTS

Ibsen (17) assumed that the black spots on nose of Herefords, Guernseys and Shorthorns are identical in formation of black spots under the white hair of Holstein, Ayrshire and possibly similar spots under the red hairs of red and white breeds. Black skin on the nose of the red short horns (nn) has approximately the same amount of black pigment as is found in the nose of blackish animals e.g. Jersey.

White hairs from above black skin spots from Holstein and Ayrshire are unique in that, diffuse red pigment is present both in follicle and in the narrow proximal region of the hair (7).

Ayrshire have "halos" (7). These surround the pigmented areas on the body and consist of black skin extending about an inch beyond coloured hairs and having mixture of white and blackish hairs. This combination of white and pigmented hairs gives the "halo" effect (7).
MATERIAL AND METHOD

Material required for this present study is chiefly the whole hairs from the body of the animals and skin pieces from different locations. The material was obtained from "The Government Dangi Cattle Breeding Farm, Igatpuri, Maharashtra State".

Whole of the herd was divided into two categories according to sex, male and female (Table No. 1). Animals in each lot i.e. Male lot and female lot were grouped according to age. This age grouping was as under:

1. Birth to six months.
2. Six months to 1½ year.
3. Adults.

Two animals, representative of each group from both categories i.e. male and female were taken for collection of hairs. Hairs were collected from three types of coat colour patches on the body of animals.

1. White patch
2. Black patch
3. Light black patch.

Hairs were picked up from the skin of animals along with their roots. The hairs were collected from white and black patches, the location of which is almost all cases fell on shoulder and black regions. In every few cases the location was from rump and forehead. But the location of light patches invariably in majority of cases
fell on hind legs and flanks. For the study of dilution factor the hairs from brown patches on the back region of adult animals were obtained. Hairs from the inguinal white spots were also collected. Approximately 300 hairs from each patch were picked up and kept in clean glass tubes which were numbered (Table No. 1). Hairs from two animals one male and other female which were red and white in coat colour were picked up in similar fashion.

The skin pieces from six animals including red and white coloured individuals were taken from tip of ear, muzzle, body skin from white and black coloured patches and skin from inguinal spots. The pieces were preserved immediately in 10% formo-saline to help fixing the tissue.

The object of collection of this material was to study the histology of hair and skin, chiefly the pigmentation and establish the relation of hair and skin pigmentation to the genetic composition of colour pattern of Dangi Cattle.

The technique followed for the present study was one that is described by Ralf Bogard and Herman L. Ibsen in (1937 (7)).

The hairs from each collected sample were studied in whole mounts. The hairs were cleaned by passing them
through the fingers. Untreated hairs i.e. raw hairs were mounted on a slide in 50% glycerine. Number of hairs mounted on each slide varied from 4 to 10. After arranging the hairs on a cover-slip which was made wet with glycerine 50%, the cover slip was slowly and carefully spread over the clean glass slide on which a drop of 50% glycerine was kept. Care was taken to avoid any bubbles of air getting under the cover-slip. Excessive glycerine was removed carefully with the help of blotting paper, without disturbing the position of hairs mounted. The slide and cover-slip were sealed together with "nail polish".

Further the bulk of hairs from each collected samples was subjected to the treatment of bleaching with $H_2O_2$ (50%). At the end of 72 hours the permanent mounts were prepared on the same lines described above. Description slip was attached to all the permanent slides.

From six animals the skin pieces were collected. Following technique (20, 21) was used for histological examination of skin.

The piece of skin was collected and put in 10% formalin saline (1:9) for fixation for 24 hours. By this process the tissue is preserved in the same state of which it was collected from the animal. Autolysis and bacterial growth is prohibited by formosaline.

After 24 hours, the tissue is cut into small pieces
with sharp knife. These pieces are washed in running water in order to remove formaline.

Further this small piece of skin was subjected to "processing" by passing the tissue through different grades of alcohol, zylo1 and paraffin (20, 21) with the help of "Autotechnicon".

Further the piece of tissue is removed from paraffin and put into liquid paraffin for "black making".

After 34 hours, the sections are cut on microtome at 5 to 6 u (micron) thickness. The ribbons of tissue are made to float on "tissue floating bath" (50° to 60° C) to which little amount of gelatin or egg-albumin is added as adhesive. Good sections are picked up on glass slides, after separating them with needle. These sections on glass slide are allowed to dry in hot air oven.

Further these slides mounted with Sections of tissue were stained with "Haematoxylin Eosin" (20, 21). Some sections were also "Safranin 0.5%".

Permanent mounts of stained sections were prepared in Canada Balsam. Description slip was attached to each slide.

With Hematoxylin Eosin staining the tissue is stained pink and nuclei take violet blue stain. Due to blue stain
taken by nuclie it was little difficult to differentiate melanin granules. To get rid of this difficulty some sections were stained with 0.5% Safranin (20, 21). In this staining, nuclei take pink stain and the melanin granules being black are well differentiated and seen.

Permanent mounts of some unstained sections were prepared in Canida Balsm after giving 3 - 4 changes of Zylool, each for one minute.

In addition to the above study of hair and skin pigmentation, the following observations were made on the animals at the Government Dangi Cattle Breeding Farm Igatpur and Dangi Cattle show Ghoti (Igatpuri).

Body Coat Colour patches, their distribution, size, location and intensity.

Pigmentation of skin, ears, muzzle, teats, external genitalia of female and the perinium in males. So also the inguinal white spots were observed in animals of both sexes and young calves. The pigmentation of horns and hoofs was curiously observed in very young calves and adults.

Pigmentation of tongue, lining of mouth and m.m. of eyes.

The above observations were strictly phenotypic in character. Approximately 600 animals were studied.
OBSERVATIONS AND DISCUSSION

The study of Genetic make up of colour pattern of Dangi Cattle of Maharashtra State, in relation to the pigmentation of skin and hair has been undertaken. It is observed that very little work has been done on colour pattern of Indian Cattle breeds. The study was intended to locate the colour genes responsible for the production of colour pattern of Dangi. With the help of these findings, the purity of this breed can be estimated. This study will help for registration of pure cattle of this breed too. With the basic understanding of the genetic make up of colour pattern, further work can be undertaken to correlate it with the productive ability of this breed. Thus one can have the cattle herd of uniform coat colour pattern with high productive ability.

The home treat of Dangi Cattle is the districts of Nasik, Ahmednagar, Kolaba, Aang and Ratnagiri of Maharashtra State.

Largely accepted coat-colour of Dangi Cattle is "black and white" with a clear demarcation between them. "Red and White" coat colour is not favoured by the breeders though such animals are occasionally met with in the home tract of Dangi. The location of black and white patches on the body of animal is not typically confined to particular area as in case of Hereford and Dutch - belted cattle.
But the large black patches are confined mostly to the back region and on the rest of the body they may fall anywhere. The white patches too, are not any way typically confined. But in majority of animals under observation, it is found that the cheeks are covered with black and forehead and bridge of nose with white patches. The switch is generally black. There is no definite proportion between the areas of black and white patches on the body. But the colour pattern of Dungi is grouped under three categories according to the proportion between the areas of black and white patches.

1. In "Bhala" (Plate No. 1, Fig. 1) more than 3/4th of the total body coat area is covered with black patches and remaining coat area is white.

2. In "Para Bahala" (Plate No. 1 Fig. 2), the proportion of coat area occupied by black and white patches is almost invariably equal.

3. In "Para" (Plate No. 1, Fig. 3) almost all of the body coat area is occupied by white.

It is not uncommon to find the animals with extreme diversity i.e. one with maximum black patches and other with maximum white. From the observations made it can be stated that the ears, muzzle, eye lids, horns, hoofs, and teats and external genitalia in females and perineum
in males are almost invariably black. Inguinal spots are commonly seen in animals of both sexes. There seems to be no sexual dimorphism in colour pattern of Dangi. However, light black patches are noted in quite a few number of animals of both sexes. In calves the black patches are generally of light colour which later turn into black.

The gene "black spotting or blackish pattern" "Bs" is responsible for the production of black coat patches in Dangi and not the gene "B" as in Holstein (17). Black is concentrated in certain parts over the body of animal forming variable sized patches. The gene "Bs" causes the black pigment to appear in skin all over the body, nose, horns, hoofs, and eyelids. The tongue in Dangi is invariably unpigmented. The lining of mouth is partially pigmented i.e. variable sized black pigmented spots are seen on the lining of the mouth. This is in contrast to the expression of gene "B" as in Angus and Holstein where, above specific areas including tongue and lining of mouth are black. The unpigmented tongue and partially pigmented area of lining of mouth in Dangi are due to the interaction of "Bs" gene with "s" gene responsible for recessive white spotting (2, 17).

In Dangi "Bs" is not fully expressed in newly born calves (2, 17). Black pigment gradually creeps in with
increasing age. The hoofs of newly born calves are partially pigmented (Plate No. III, Fig. 3A, B). These expressions of "Bs" have been observed in Dangi Cattle. With increasing age the hoofs of newly born calves become fully pigmented. In Jersey and Ayrshire carrying gene "Bs" males develop more black than the females (3, 32, 33), but no such sexual dimorphism in coat colour is observed in Dangi Cattle. The black patches on the body of calves are of light black colour, this is due to less of black pigment in the hairs comparatively towards the tip at this stage of life. But later on as the age increases the same light patch turns into black (Table No. I).

The black hairs of Dangi show a typical "Bs" pattern picture under microscope (Plate No. III, Fig. 2-B). The whole mouts do not look solid black. Black "Bs" hair under low power show faint differentiation between medulla and cortex, but under high power it is more distinct. Black "B" hairs from Holstein show solid jet black picture under low as well as high power (17). The chief difference in "Bs" hairs of Dangi and "B" hairs of Holstein lies in the amount of black pigment and its intensity of extension. The black clumps in black "B" hairs are intensely packed giving a solid appearance. This is due to the presence of extension factor "E" modifier of gene "B", and is responsible for complete extension of black pigment in all
individual hairs that are pigmented due to gene "$^R$" 
(2, 17). According to Ibsen (17) quoted by Baldwin,
Gilmore et al (2) neither "$^B$s" nor "$^C$" (red) can be
expressed except in the presence of "$e$" the absence
of extension factor "$E$". Black hairs of Dangi look
quite black on the body of animal but whole mounts
may look reddish. This is due to gene "$^B$s" present in
Dangi, lacking extension factor "$E$". The black "$^B$s"
hairs of Dangi show the diffuse transparent red pigment
on which black pigment in clumps is distinctly spread.
The black hairs of Dangi differ considerably in their
degree of blackishness which is entirely due to
varying amount of black pigment in the cortex. Such
variation in the degree of blackishness of "$^B$s" hairs
is equally well observed in the animals of both sexes
and as such in Dangi there is no sexual dimorphism in
the expression of "$^B$s" which according to Baldwin,
Gilmore et al (3) and Wentworth (32, 33) exists in
Jerseys and Ayrshire.

Bleaching with $H_2O_2 50\%$ causes black pigment in
"$\text{B}$" hairs of Dangi to become colourless as it does in
those from "$\text{B}$" animals. But time taken by "$\text{B}$" hairs of
Dangi for complete bleaching is less than that of "$\text{B}$"
hairs of Holstein. The bleaching effect in "$\text{B}$" hairs
of Dangi is seen within 48 hours to 72 hours and diffuse
transparent red pigment is revealed, (Plate No. III, Fig
4). This confirms Ibsen's statement (7, 17).
Like "B" gene in Holstein and Angus, "Bs" gene in Dangi is responsible for the presence of black pigment in the body skin, nose, horns and other parts. But from the histological study of sections of skin, muzzle (Plate No. III, Fig 1) and ear tips of Dangi, it is revealed that the black pigment is not plentiful as it is in "B" animals. The black pigment in the skin, muzzle is comparatively less in proportion that in the hairs. The pigment is located in the Str. germinativum or the basal layer of epidermis.

Generally in "B" and "Bs" animals the tongue is black (17). Jerseys carry "Bs" gene with "s" gene which according Insen (17) quoted by Baldwin, Gilmore et al (2) is responsible for black tongue in Jerseys. Dangi even though carries "Bs", has unpigmented tongue and partially pigmented lining of mouth. This is chiefly due to the presence of "s" recessive white spotting gene in Dangi, which interferes the expression of "Bs" in the tongue and lining of mouth (17).

"M" and "L" genes modifiers of "Ps" exhibiting sexual dimorphism in Jerseys and Ayrshire carrying "Bs" gene reported by Wentworth (32, 33) cited by Insen (17) are not existing in Dangi.

There is a form of dilution due to a recessive gene "i" acting of "Bs" expressing it in lighter shades of
black (plate No. III, Fig 2-C). Number of adult animals of both sexes were observed with such light black patches. According to Ibsen (17) a recessive dilution factor "i" acting on " Bs" exists in dairy breeds of Jerseys and Guernseys - making them of lighter shades of red. Hairs from such patches look brownish to the naked eye. Under microscope such hairs were found to contain less amount of black granules on the back-ground of diffuse transparent red pigment making the hairs to appear of lighter shade of black. H₂O₂ bleaches the black pigment in these hairs earlier than " Bs" hairs from which " i" is absent.

It is certain that the character brindle " Br" is completely lacking in Dangi Bread. Had it been existing in Dangi, a number of animals would have had brindle patches instead of genes " Bs" and " Br" (17).

Dangi animal is not self " S" as Aungus and Jersey and therefore shows white spotting on the body coat. The gene responsible for the expression of white spotting on body coat in Dangi, is " recessive white spotting gene" - " s". Presumably, " s" does not allow the black pigment either due to " t " or " Bs" factor to express in hairs, thus resulting into white coat patches on the pigmented body skin (17). The skin under white coat is pigmented. Like Holsteins carrying " s " gene, in Dangi the white patches are not typically confined to particular area as it is confined to particular area in Hereford " S_H " pattern and Dutch belted " S_H " and colour sided " S_C " animals which
in these breeds is a dominant character.

From the observations made on Dangi Cattle, it seems that the gene "s" is quite variable in its expression, perhaps this is due to the modifying factors "Lw, lw and Pl, pl" acting on "s" and therefore non-germinal in nature (17, 18) as in Dangi and so also in Holstein the white patches on two sides of body are generally unlike. According to Lanprecht (1926), Dunn, Webb, and Schneider (1923) quoted by Ibsen (17) there exists single pair of modifiers responsible for the varying amount of white area on body coat in Holstein. These modifiers which are entirely quantitative in nature are the factors causing small amount of white "Lw" which is incompletely dominant to its allele "lw" causing more amount of white on body coat. Many Ayrshire are almost entirely white "lwlw" and Guernseys and Shorthorns invariably have a small amount of white spotting "Lwlw" (17). These modifiers of "s"; "Lw and lw" seem to be existing in Dangi in the form of dominant homozygotes "Lwlw", heterozygotes "Lwlw" and recessive homozygotes "lwlw". This can be well supported and interpreted from three categories of coat colour pattern existing in Dangi. Thus "Bahala" category which shows small amount of white coat area on the body is dominant homozygous form of "small amount of white spotting" - "Lwlw". The "Para Bahala" category exhibiting nearly equal amount of white and black coat colour area is
heterozygous form "LwLw" and the "Para" category exhibiting the coat colour almost entirely white is recessive homozygous form "lwlw".

"Pl" a modifier of "s", recently brought into picture by Ibsen and Riddell (1931) quoted by Ibsen (17), exists in Dangi. This modifier "Pl", causes the animal with pigmented coat to a large extent below the knees. In the pigmented legged "Pl" animals, the pigment seems to be concentrated around hoofs and extend upwards upto knee and pigmented spots on leg coat are seen (17, 18). The gene "Pl" is found in ayrshire as these animals have pigmented coat below knee. Holstein, Guernseys and other breeds are "plpl" and therefore they are entirely white from knee to the hoof. From the observations made this seems quite possible that Dangi carry the gene "Pl" for pigmented legged coat as almost all animals have pigmented coat spots on the region between knee and hoof.

According to Pankuist and Bowman (1923) cited by Ibsen (17) there are three pairs of genes affecting the amount of white on heads in Holstein and Red white Swedish breed. Entirely pigmented head is due to the joint action of three recessive genes; and entirely white head due to two homozygous dominants plus either homozygous or heterozygous third dominant (17). Animal carrying "LwLw" or "LwLw" have less white on head than the animals with "lwlw" (17). In Dangi the head is never entirely pigmented.
But there may exist some correlation as it exists in Holsteins (12, 28, 29, 30) between head pattern and white on the body and legs indicating that the genes "Lw, lw and Pl, pl" control the head pattern in Dangi. In "Bahala" (LwLw) the body coat is occupied more by black patches than white so also the head. In "Para Bahala" (LwLw) the area occupied by black and white patches is generally equal so also the head pattern. In "Para" (LwLw) almost the whole body coat is white and entire head also is white. But according Treece (30) cited by Treece, Gilmore et al (28) no head pattern breeds true. But there is an association between head pattern and proportion of pigmented area on the body (29). This fact seems to be existing in Dangi cattle. According to Ibsen (18) "Wh" a factor for white head is responsible for increase in white area on head. "Wh" is linked with "Sb" spot breaker which has more effect on body than on head (18).

According to Ibsen (17) all "ss" animals have white switch. But the Dangi cattle in contrast to this have black switch even though they carry "ss" recessive white spotting gene. But few animals of "para Bahala" category show the admixture of white and black hairs in switch. And "Para" category show white tail. Thus it looks logical that the factors "Lw, lw and Pl, pl" may be associated with the switch colour in Dangi. According to Hooper (1921) cited by Ibsen (17) the white switch in Jerseys
carrying "S" gene, is due to separate gene governing white switch colour.

Ibsen has revealed the fact that the animals with "ss" have invariably unpigmented tongue even though they carry "B" or "Bs" (17). Dangi has unpigmented tongue which is due to interaction of "s" with "Bs" lacking extension factor "E", thus preventing the black pigment from appearing in the tongue.

Of number of white hairs examined from Dangi animals, very few are entirely devoid of pigment. Almost all white hairs lack the pigment in the cortex and this is why they look white. Majority of hairs possess black pigment in varying amount in medulla (Plate No. III, Fig. 2A). The black pigment in medulla is not densely packed but loose clumps are seen on clear white background. This is due to interaction of "ss" and "Bs" lacking extension factor "E". This also confirms Ibsen's statement that white hair do not have red pigment. It is observed, the white hairs from calves are having less amount of black pigment in the medulla and it has not extended throughout the length of hair showing the creeping in tendency of pigment with increasing age. All white hairs from Dangi lack black pigment in the cortex. This is due to the presence of "ss" and "ee". The combination of "ss" and "ee" prevents the black pigment appearing in cortex of hair and thus making the hairs white. White hairs from the inguinal white spots
"In" (albino spots) from Dangi also possess the black pigment in medulla, but the amount and intensity is very less.

Bleaching of white hairs from Dangi with $H_2O_2$ revealed no red pigment. This confirms Ibsen's statement that the white hairs do possess the black pigment but not red pigment (7, 17).

Skin under the white coat patches from Dangi was studied under microscope. This skin is pigmented and possess black pigment in the form of small scattered granules. This is similar to the pigmentation of skin under white coat in Holstenins carrying "ss".

Skin sections from the inguinal white spots in Dangi were studied. It is revealed that there is no pigment in the skin from inguinal spots, confirming it to be an "albino" spots.

The gene roan "N" which is completely dominant, causing hairs of any colour to become unpigmented and therefore white (14, 17), does not exist in Dangi. Heterozygotes "Nn" are roan. "N" in homozygous condition (NN) is epistatic to "ss". The Dangi animals are "nn". If 'N' would have been existing in Dangi, then heterozygote "Nn" would have had shown black patches as roan patches and white patches to be blue gray - but such expression does not exist in Dangi.
It seems, Dangi Cattle do not carry recessive white factor "wn" which in homozygous condition is epistatic to "B" and "Bs", and prevents the formation of pigmentation in the hairs, but have no effect on the skin. If "wn" would exist in Dangi as homozygous, then whole coat colour would have been "Silver gray" as Nellores (17, 25). Likewise the heterozygous condition "Wnwn" is also ruled out in Dangi, because sometimes in the course of breeding, two heterozygotes would produce homozygous "wnwn" individual making it to be "Silver gray" as Nellores (25). Therefore Dangi is "WnNn".

Dominant white "Wp" which is carried by white English Park Cattle does not exist in Dangi. "Wp" causes the body coat completely white. "Wp" animals produce both non-whites and self individuals indicating "B" or "Bs" and "S" exist in "White English Park" breed. Such incidences are not met with Dangi and therefore Dangi is "wpwp". A "wpwp" animal would merely be an animal that did not carry dominant white "Wp".

In Dangi Cattle, almost in all individuals, the inguinal white spotting "In" which is a dominant character is observed in animals of both sexes. (Plate No. II, Fig. 1). In females these white spots are located on either side of teats and udder, and in males on either
side of rudimentary teats, sheath and scrotum. Sometimes these spots extend up to brisket and dewlap. These inguinal white spots are due to the dominant factor "In" which is epistatic to "s".

Hairs from these inguinal spots were examined microscopically which showed slightly different picture from "ss" hairs, in that these "In" hairs possess very little pigment in the medulla and none in the cortex. Very few hairs were completely devoid of pigment either in the cortex or medulla.

The skin from inguinal white spots was examined microscopically and found to be devoid of pigment indicating that these spots are "albino".

The recessive whitening factor "w" causing the black hairs due to "B" or "Ps" whitish, exists in Jerseys. Jerseys carrying "w" are of "fawn" colour. Dangi do not carry this gene in recessive condition because no whitening effect on black "Bs" hairs is noticed and therefore Dangi is "ww" which prevents whitening expression of "WW".

The Dangi Cattle do not carry gene "Ps" responsible for pigmented (black) skin spots, on otherwise brown skin areas (15). According to Ibsen (17) the gene (Ps) causes the black spots of varying sizes on the nose of Hereford, Guernsey and Shorthorn from which both "B" and "Bs" are
absent. In the absence of both "P" and "Ps" gene, no black spots should be seen anywhere on the body of animals. But pigmented (black) spots are seen on nose of Hereford, Guernsey and Shorthorn, which is due to the gene "Ps". The formation of these spots due to "Ps" is identical to the black skin spots under white hairs of Holstein, Ayrshire and Dangi. The combination of "b" or "Bs" with "s" generally results into black as well as white spots on the nose (17) but such an expression is not seen in Dangi carrying "Ps" and "s" genes. This leads to the assumption that a separate dominant factor to "s" is governing the black muzzle colour in Dangi. According to Pitt (1920) quoted by Ibsen (17) there is dominant factor for pigmented nose. Berge S (1957) states that the muzzle colour is determined by single pair of genes (6). The muzzle section of Dangi under microscope revealed a plentiful black pigment (Plate No. III, Fig 3).

From the observations made, it is noticed that the muzzle, ears, teats; and external genitalia in females are of jet black colour in all the animals of three coat colour categories i.e. "Bahala", "Para Bahala" and "Para". In the "Para-Bahala" animals where the coat colour is more white than "Bahala" animals and in "Para" animals which almost entirely are white, there is no change intensity of colour of muzzle, ears etc. in any of these categories. Some fact holds good for the animals
having dilution factor acting on "Bs" making black patches lighter. This leads to assume that the Dangi cattle carry a dominant factor here designated - "ED" in homozygous condition, governing the jet black colour of muzzle, ears, teats etc. (Pl. No. II, Fig. 2, 3). "E" designated for black ears and D standing for Dangi. However heterozygotes do not exist. The factor "ED" for black ears differs from the factor "be" black ears described by Hancock (15).

At Government Dangi Cattle Breeding Farm Igatpuri, two animals, one male (Mahendra Bullock) and another female (Devyani Heifer) are observed to have the coat colour as "Red and White". The breeding data reveals that these individuals are from typical breed colour patterned (black and white) Dangi parents. It is obvious that these red and white animals completely lack the factor "Bs" responsible for black pigment in skin, nose, eyelids, tongue, lining of mouth, horns, hoofs and nictitating membrane. It is observed that these Red and White individuals have muzzle, skin, eye lids, horns, hoofs and nictitating membrane of brown colour. Such an expression is only possible in the absence of "B" and "Bs". Quite a few number of animals having such colour pattern have been observed at Dangi Cattle Show Ghoti, Igatpuri. It is certain that these "red and white" individuals must be of "bb bsbs" genetic composition which gives an opportu-
nity to Red gene "R" to express (17). Accordingly these "bb" bsbs" animals must have come from the black and white parents both of which must have had "B" gene in heterozygote condition i.e. "Bsbs" as genetic composition.
CONCLUSION

It is concluded that the gene "Black spotting Bs" is chiefly responsible for the production of variable sized spots of black colour on the body coat of Dangi cattle. Gene "Bs" is only expressed in the absence (ee) of extension factor "E".

In Dangi "Bs" is also responsible for the black pigment to appear in the muzzle, skin, horns, hoofs, eyelids and hairs. Its expression in tongue and lining of mouth is interfered by the recessive white spotting gene "s" and therefore tongue is unpigmented and lining of mouth is partially pigmented.

"Bs" is not fully expressed in newly born calves. Young calves generally have light coloured black patches and partially pigmented hoofs which with increasing age become black.

No sexual dimorphism has been observed in Dangi Cattle. But there is a form of dilution due to recessive dilution factor "i" acting on "Bs", making the black patches of lighter shade. This effect is seen in both male and female adult individuals.

Possible existence of characters brindle "Br" and Roan "N" in Dangi has been ruled out.

Dangi is not self "S". But they carry a "recessive white spotting gene "s" which is responsible for the
production of variable sized spots of white colour on the body coat. "s" along with "Bs" gene is responsible for the unpigmented tongue and partially pigmented lining of mouth in Dangi.

Dangi Cattle carry "Lw, lw" and "Pl, pl" the modifiers of "s" recessive white spotting gene. "LwLw" animals are "Bahala" who possess small amount of white on the body coat. "LwLw" animals are "Para - Bahala" and so possess nearly equal amount of white and black area on body coat. "lwLw" animals are "Para" who possess more amount of white area on body coat to the extent that almost whole of the body coat is white. The gene "Pl" is responsible for the black pigmented coat on the legs below knees. "PlPl" condition exists in "Bahala" "Plpl" in "Para Bahala"; and "plpl" in "Para" where the coat below knees to the hoofs is entirely white.

The factors "Ps" for pigmented (black) skin spots and "Wp" for dominant white in "White English Park Cattle", are absent in Dangi. The absence of these factors is designated by "psps" and "wpwp" in Dangi.

The character "wn" which in homozygous condition is responsible for the production of "Silver gray" colour in Nellores, is absent in Dangi. But the dominant allelomorph of "wn", which is designated by "Wn" is present in Dangi. Wn prevents the expression of "wn".
The gene "wm" the recessive white (silver grey) is epistatic to "b" and "B" both.

A recessive factor "w" responsible for whitening effect—a form of dilution—on black hairs of Jersey making them of "fawn" colour, is absent in Dangi. But "w" the dominant allelomorph of "w", which prevents the expression of this character "w" is present in Dangi.

The factor "In" responsible for dominant inguinal white spotting, exists in Dangi. These white spots which are "albino" in nature are observed in the inguinal region of animals of both sexes. Further it has been observed that inguinal spots are less in number and smaller in size in young calves. As these calves become older, with increasing age, the number of inguinal spots and their size increase. This suggests that such an exhibition of a character of inguinal white spotting would be due to either a separate factor acting on "In" which partially inhibits its "In" expression to full extent in early stage of life; or it may be due to a "delayed action of gene" "In itself which is unable to express fully in early age of life. This peculiar expression of character "In" in Dangi, requires further investigation in detail.

It has been concluded that in Dangi, a dominant homozygous condition of a gene, here designated as "sDn"
is responsible for the black ears and perhaps also
governs the black colour of muzzle. It is necessary to
proceed with the work on the factor \( E^D \) to study its
mode of inheritance, its interaction with other genes and
modifiers if any acting on it.

Possible existence of association between the
genes "Lw, lw; Pl, pl" modifiers of "s" and the expression
of head pattern in Dangi requires to be worked out as has
been worked out in Holsteins (12, 28, 29, 30). Likewise
it is necessary to find out the possible genetic bases
for the expression of black switch in great majority of
animals which is contrary to the statement made by Ibsen
(17).

With basic understanding of colour pattern of Dangi,
it is of prime importance to proceed with the work on a
correlation between genetic composition of colour pattern
and economic characters in Dangi Cattle.

The Genetic Composition of coat colour pattern in
Dangi Cattle:
Formula for "the Genetic Composition of Colour Pattern of Dangi Cattle".

bb dd BsBs ee ii brbr nn ps ps ss llww PlPl wpwp WW WnWn

\[ E^D \]

Bsbs  Lwlw Plpl
bsbs  lwlw plpl

Key to the Gene notation:

b : Absence of 'B'
d : Absence of dominant dilution factor 'D'.
Bs : Black spotting gene.
e : Absence of Extension factor "E" acting on "B".
i : recessive dilution factor. Normal allele of "I".
br : Normal allele of Brindle "Br".
n : No roan, Normal allele of Roan "N".
ps : Absence of pigmented black skin spots "Ps".
s : recessive white spotting factor.
Lw : Small amount of white modifier of "s".
lw : Large amount of white modifier of "s" and allelomorph of incomplete dominant factor "Lw".
Pl : Pigmented legged factor.
pl : Normal allele of Pl.
wp : absence of dominant white spotting in English Park "Wp".
W : Allele of recessive "w" causing whitening in Jersey.
Wn : Allele of recessive white "wn" causing "Silver gray" in Nellores.
In : Dominant inguinal spotting factor.
ED : Factor for black pigmented ears and possibly muzzle in Dangi.
SUMMARY

Colour and colour patterns of cattle in general with its formation, utility and importance with a detail account of melanin is given.

A review of literature of the work on "Cattle Colour Inheritance" by Ibsen (1933) and "Its Relation to the pigmentation of skin and hair" by Bogart & Ibsen (1937) has been made in detail.

The observations for the present study of colour pattern in Dangi Cattle have been made on the animals of Government Dangi Cattle Breeding Farm, Igatpuri, Maharashtra State, and the Dangi Cattle Show at Shoti (Igatpuri).

The technique employed for the present study of "Genetic make up of coat colour pattern in Dangi Cattle of Maharashtra State", in relation to the pigmentation of skin and hair is based on the one which is described by Bogart and Ibsen (7) with slight modification.

Detail account of the genes responsible for the colour pattern of Dangi Cattle is given in the Discussion.

The formula for the "Genetic Composition of Colour Pattern of Dangi Cattle" has been given with utilizing the symbols for colour genes designated by Ibsen (17).
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<td>Haviya</td>
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<tr>
<td>Red Hairs</td>
<td>33</td>
<td>White Hairs</td>
<td>39</td>
<td>Red Hairs</td>
<td>40</td>
<td>White Hairs</td>
<td>41</td>
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<td></td>
</tr>
<tr>
<td>Red and white</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pandu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dilute - light</td>
<td>hairs</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dilution Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

W = white hairs from white coat patches. B = black hairs from black coat patches. L = light hairs from light black coat patches.

Numericals indicate the slide numbers of the permanent mounts prepared from respective hair samples.
### Table No. II

**Bleaching effect with $\text{H}_2\text{O}_2$ 50% after 72 hours - on hair samples from Table No. I.**

<table>
<thead>
<tr>
<th>Name of Animal</th>
<th>M A L E</th>
<th>Name of Animal</th>
<th>F E M A L E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Birth to six months</td>
<td>Six months to 1½ year</td>
<td>Adult</td>
</tr>
<tr>
<td>----------------</td>
<td>---------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>Dama</td>
<td>W B L</td>
<td>'1A '2A '3A</td>
<td></td>
</tr>
<tr>
<td>Tutari</td>
<td>++ '++' ++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dama</td>
<td>'4A '5A '6A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ragini</td>
<td>++ '++' ++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pakhrya</td>
<td>16A '17A '18A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ravlya</td>
<td>22A '23A '24A</td>
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</tr>
<tr>
<td>Searaj</td>
<td>++ '++' ++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ravlya</td>
<td>21A '22A '23A</td>
<td></td>
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<tr>
<td>Mahendra</td>
<td>Red hairs 38A</td>
<td>White hairs 39 A</td>
<td>White hairs 40 A</td>
</tr>
<tr>
<td>(Red and White)</td>
<td>++</td>
<td>++</td>
<td>(Red and White)</td>
</tr>
<tr>
<td>Pandu</td>
<td>Light hairs 42 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Dilution Factor)</td>
<td>+++</td>
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</tr>
</tbody>
</table>

**Numericals with suffix 'A' indicate the slide numbers of permanent preparations of hairs after bleaching action.**

**Bleaching Action:**
- = Nil
+ = Slight
++ = Marked
+++ = Well marked.
Plate No. 1.

1. Bahala: Animal showing most of the body coat covered white patches.

2. Para Bahala: Animal showing body coat with nearly equal amount of black and white patches.

3. Para: Animal showing body coat almost white.
Plate No. II

1. Inguinal white spots: Animal showing "white spots" in inguinal region.

2. Ears: Animal showing black ears "D".

3. Teats: Animal showing black teats.
Plate No. III

1. Section Muzzle: Unstained section of muzzle showing black pigment in basal epithelial cells.

2. Untreated Hairs of Adult Animal:
   A. White hair showing black pigment in medulla and no black pigment in Cortex.
   B. Blackish hair showing black pigment packed in medulla and in cortex with less intensity especially towards tip.
   C. Light hair showing black pigment in clumps in medulla and the cortex showing loose clumps of black pigment on the background of diffuse transparent red pigment.

3. Untreated hairs of calf:
   A. White hair showing practically no black pigment in medulla.
   B. Black hair showing black pigment in lower 1/3rd and rest showing diffuse transparent red pigment.

4. Bleached blackish hair:
   Blackish hair (Plate No. II Fig. No. 2B) on bleaching with H$_2$O$_2$ 50%, showing bleaching of black pigment revealing diffuse transparent red pigment.