

5751

T H E S I S

for the Degree of M.D., University of Edinburgh

---

MATERNAL IMPRESSIONS AND COLOUR HEREDITY.

by

D. BROWN, M.B., Ch.B.,

---

April 1911.



# MATERNAL IMPRESSIONS & COLOUR HEREDITY.

---

## INTRODUCTION.

---

The primary object of this thesis is to set forth certain experiments and their conclusions as to the influence of maternal impressions on colour heredity. It will be shown that the belief in such an influence, at work in nature is widely credited, and that a solution of the questions, - Is there such a work at play at all? - and if so, - What is its extent? - is of the utmost importance, not only to the breeder but also to the scientist. I do not intend going deeply into the history of maternal impressions, nor would it serve any good purpose to relate all the numerous examples, cited by breeders, of the effect this influence has in the breeding of stock. Certainly these are mostly extremely interesting, but many are found, on being followed up, to have no foundation whatsoever, while others are too lacking in specific detail to be of any use in a scientific discussion of the subject. This thesis is not to be reckoned otherwise than an unbiassed attempt to investigate experimentally, the/

the subject of Maternal Impressions, as it bears on colour heredity and to try to account for those cases which are at present put down to its influence.

Since the work of Gregor Mendel was discovered much has been done to elucidate the workings of heredity in relation to the inheritance of colour. Many cases formerly put down to the influence of Maternal Impressions have found their true explanation. Can all such cases be explained by the light of Mendelism? It was to investigate the cause of those cases, which have, up till now, been attributed to the Maternal Impression Theory, that the following experiments were undertaken. Every possible chance that one could think of, was given for the manifestation of such an influence - after all necessary precaution had been taken, and it now remains to be seen what were the results obtained.

#### HISTORICAL NOTE.

---

The subject of Maternal Impressions is one which has aroused interest and discussion in all ages, and in all lands ever since Jacob (1) placed his peeled wands of green poplar, hazel and chestnut before the flocks of Laban. It is interesting to note that nearly/

nearly all the works dealing with the theory of maternal impressions, treat of it as it affects the human species, and it is only incidentally that its working amongst the lower animals is mentioned at all. Therefore much of the history of the subject is irrelevant to the present thesis. Those desirous of studying it, will find a very full record of the literature in the works of Ballantyne, (2), Preuss(3), Delage (4), Prosper Lucas (5), and in The Catalogue to the Surgeon General's Office at Washington.

What I would chiefly draw attention to is, that "in its earliest beginning it was not specially a teratogenic theory; but rather one used to explain how the young of men and of animals came to be of special colours and especially of a tint differing from their parents".(2) Up to the time of Empedocles (6) (500 B.C.), it would appear to have been used simply as a "colour" theory. After this though still continuing down to the present day, especially amongst breeders, as an explanation of differences in colour heredity, many additions have been made to it; some so absurd that there was no wonder that the whole theory was, by many, summarily condemned. Still it survived unchallenged till Blondel (7) attacked it in the beginning of the 18th century. He says:- "I am the first that has ever writ on this side/

side of the Question". Since then, though many have arisen to condemn it, the belief in the theory will be shown to be still alive. Surely there must be some truth in a theory so ancient and so persistent. In the whole literature I can only find the record of one experiment with animals - which I shall refer to later - though Preuss (8) and Harvey (9) give directions how certain experiments may be conducted.

PREVALENCE of the THEORY at the  
PRESENT TIME.

---

Even at the present day, notwithstanding all that has been said and written against it, the belief in the potency of the maternal imagination finds many supporters.

"Many of our foremost breeders of stock are impressed with the belief that certain colours present to the eye of the parent animals and particularly of the female, at the time and in the act of their coupling together, and to the eye of the female both before and during pregnancy, influence the colour of the progeny. They make this belief a practical influence of action in the breeding of their stock, in order either to prevent or to secure the admixture of any particular colour in the offspring different from that of the parent animals."

So wrote Harvey (10), sixty years ago,  
and/

and it still stands true to-day. One of our foremost breeders (11) of shorthorn cattle has made use of this influence repeatedly, while Mr Cruikshank (12) says that he has had too many proofs of the agency of the cause in question to allow him entertaining any doubt on the subject. Numerous other examples could be cited of the prevalence of this belief amongst our Scottish breeders; but let these suffice. It may be that they read their experiences awrong and, from their ignorance of the laws of heredity, and more especially, of the recent work of the Mendelian School, ascribe the results they obtain to what seems to them the only efficient cause. Yet, provided such views are erroneous, they cannot be blamed for entertaining such beliefs as are commonly taught. The breeder, excluding experience for the moment, gets his knowledge from the books and newspapers that bear on his work. Now let us see what he is taught to believe.

Professor Wallace (13) says : - "Imagination is believed to come into play in breeding, especially with regard to colour. The colour of any object at which an animal looks, while conceiving or during the early stages of pregnancy may sometimes govern the colour of the young, as the following examples/

" examples go to testify", and then proceeds to give the examples.

Prof. J. Wortley Axe (14), in a recent work says:-

"There can indeed be no doubt that the nervous system does operate largely in determining colour in some cases because the fact has been demonstrated. Jacob's device of putting straked rods in view of the flock which he was attending in order to secure a liberal proportion of straked animals for his own share, was palpably successful, and more recent experience has shown to the breeder's cost and annoyance, that the determining effect of colours on the imagination of animals through the eyesight is often marked".

I shall now give the opinion as expressed in one of our leading Scottish Agricultural papers (15) in answer to an enquiry on this subject. I do not lay much stress on these answers. Still, they are interesting as showing the current belief, and no doubt they have some influence in forming public opinion.

The Question was -  
 "MATERNAL IMPRESSIONS" - "Is the colour of a young animal ever due to an impression which its mother receives at the beginning of, or during pregnancy"?

1st Answer.

"MATERNAL IMPRESSIONS". "It is extremely improbable that colour is ever influenced by impressions which the mother receives at the beginning of, or during pregnancy".

2nd Answer.

"MATERNAL IMPRESSIONS". "All books on laws of heredity and breeding remark on this possibility and there can be little doubt that it sometimes occurs".

So much for the breeder and his views. Now let us turn to the medical man and see what his views are on the subject. The medical profession are generally taught that the theory of maternal impressions is "an archaic belief and should be relegated to the limbo of impossible things". Still there are some who seem to have doubts. In a discussion on "Heredity in Disease" Dr. Leslie Mackenzie (16) says:-

"Dr. Ballantyne's remarks on maternal impressions are valuable because he has pretty well done for that department of uncritical belief what Weismann did for the alleged inheritance of mutilations. Yet the so-called evidence, for such impressions seems to me frequently stronger than the evidence for inheritance of acquired characters".

Even Dr. Ballantyne (17) a recognised authority on the subject admits that the 19th century has closed with the subject still being debated, and draws/

draws notice to the "extraordinary rejuvenation of the ancient doctrine among the obstetricians of the United States of America", in connection with which rejuvenation we may note the articles by Fordyce Barker (18) and Dr. S. C. Busey (19), both of whom strongly support the theory of maternal impressions. But here again, though not entirely, the evidence brought forward has mostly to do with the human species.

So that to sum up, we may say, that breeders accept the theory, while medical men, in the most part, do not accept it, and yet are too cautious to deny it altogether. Even the latest works on heredity cannot get beyond "probability"; - Doncaster (20) saying that "the evidence available is probably insufficient to support any other view than that of accidental coincidence, while Delage (21) sums up as follows - "l'influence des conditions transitoires des parents au moment de la conception sur l'enfant n'est pas suffisamment établie; les états de l'esprit paraissent n'en avoir aucune; pour les dispositions de santé; on ne sait rien de précis".

#### ITS IMPORTANCE.

The subject of maternal impressions is as important to the medical man as it is to the breeder.

The/

The former is extremely likely to be asked his opinion whether such and such a deformity in a child, is due to a certain impression its mother received during her pregnancy, or he may be called in to allay the maternal fears that some injury has taken place to her unborn babe. The subject has before now come up in a court of law, and the medical man been questioned on it in the witness box.

Even from the breeder's point of view, the question is one that requires careful consideration. Can they use this agency with any hope of success in getting the desired result? If not, they will be saved the futile trouble and expense of trying it and have their minds profitably turned towards a study of the true laws that bear upon their work.

Equally to the student of heredity, a satisfactory solution of the question is of vast importance. Is he to reckon maternal impressions as a cause of variation and to bear this possibility in mind in the interpretation of the results of his experiments, or, can he totally neglect it as a thing that never occurs?

NECESSITY for a SOLUTION & REASONS why the QUESTION  
HAS NEVER BEEN SOLVED.

---

It will now be recognised from what has been said of the prevalence and importance of the subject/

subject that a definite solution is urgently called for. There still seems to be much doubt on the subject. Before attempting any solution we may well study first the reasons why the subject of maternal impressions has remained so long unsolved. Why have the supporters of the theory failed to prove it? Why have its opponents failed to disprove it?

In answer to the first question it must be admitted that though many facts suggested the probability of the presence in nature of such a theory, they would not bear a critical scientific examination. As Harvey (22) has remarked most of the cases brought forward, supply one with "information of a general kind sufficient to excite further inquiry, but wanting in specific detail", and then again as Blondel pointed out, much of the evidence is based on the fallacy - "post hoc ergo propter hoc". Some of the cases brought forward in proof were no doubt, due to coincidences, though as J.Arthur Thomson remarks, this is a very unsatisfactory word to use. The long period of gestation of most of the animals, among which this force was supposed to act, no doubt prevented any idea being formed of what was normally to be expected in breeding and cross breeding, where there was no possibility/

possibility of maternal impressions playing a part. In other words the problems of colour heredity were not understood and until these are properly mastered no definite conclusions as to the influence this power may exert in the inheritance of colour, can be arrived at. Thanks to Mendel and his followers, we seem at last to have got upon the right road.

Another very obvious reason why no positive proof or a suggestive negative for that matter, was forthcoming, was that no definite experiments were undertaken with the object of gaining such proof.

Turning to the opponents of the theory, we at once recognise that they could hardly be expected to prove a negative. It is obvious that the burden of the proof lies with the supporters of the theory and, until they could produce undeniable evidence, the opponents would not admit their case.

Another way would have been for the opponents to give an explanation of all the cases brought forward. This they could not do. No doubt many cases formerly put down to this theory have been explained. For example, the theory is no longer used to explain the cause of monsters, intra-uterine deformities etc.etc. Yet there still remain some cases unaccounted for, and surely we are justified/

justified in carrying out certain experiments to see whether these can or cannot be explained by the maternal impression theory. The most important reason, perhaps, given by the opponents why we should not expect such a cause to be present in nature is our lack of knowledge of a "modus operandi", but, as J. Arthur Thomson(23) says, "It is always unwise to speak of impossibilities in regard to matters which are inadequately known and imperfectly understood. That we cannot imagine the nature of a physiological nexus does not prove its non-existence", and again, "We must remember that for a prolonged period the unborn child is part and parcel of the mother - almost an integral part of herself, and we are beginning to know enough of the influence of mind upon body to make us cautious in dogmatising as to the possibilities of what Ballantyne finely calls "the mysterious wireless telegraphy of antenatal life".

WHAT DOES A STUDY of our PRESENT DAY KNOWLEDGE LEAD  
 ONE to EXPECT?

---

Let us examine in the light of present day science the possibility of maternal impressions playing a rôle in nature? It is extremely important to do/

do so as the trouble of carrying out a long series of experiments will be saved if, with a little investigation and study of recent research, strong evidence be found against the probability or even possibility of such a theory.

It is admitted, I think, that the health of the mother reacts on that of the child. Shock, distress and the like have a prejudicial effect on the unborn, vide, the stigmata found on the children born after the Franco-Prussian war. So much is granted by the scientists of to-day. Few, now-a-days, thanks to the works of Ballantyne, believe that deformities in the foetus, monstrosities, mother's marks etc., are due to some impression the mother has received during her pregnancy, but as Dr. Tuke (24) remarks "many appear unable to see any alternative between admitting all the absurd stories about mother's marks and denying maternal influence altogether". It seems to me that if we are to find anything of value, it is not by examining the additions that have been made to the theory since it was first promulgated, but by taking it in its simplest form. May it not have been overloaded with such absurd and extravagant views - as that it could account for the origin of/

of monsters etc., that it became top heavy, and fell to the ground. Hence it is that I have decided to study the question of maternal impressions as it bears on colour heredity - the form in which the theory first appeared.

Much research work in heredity having been done since the subject of maternal impressions last received any considerable amount of attention, we are now enabled to view the theory in a new light. The subject really falls under the heading of experimental Embryology, yet a knowledge of heredity is essential. We must know, as far as possible what results are to be expected from a given mating of two animals before we can say that we have influenced the result by outside agencies. It is, in fact, a case of interfering with the expression of the inheritance of a particular character in an animal, and is comparable to environmental influence on any member of a species. It is well known that changes of environment influence the characters, including colour, of an animal. Can then changes of environment (which is its Mother's body) of the unborn animal - influence its characters including its colour? A priori, there seem strong reasons for believing that they can. We know that many of the lower animals can be made to change their colour/

colour for example "Lowering the temperature of the caterpillar box may be followed by curious aberrations of colour in the moths and butterflies, especially in the direction of melanism" (Standfuss, Fischer, & others) (25), and Professor Poulton has shown "That the caterpillars of the small tortoise shell for instance, are for a short time so sensitive that those in a white or gilded box have light or golden pupae, while those from the dark box have dark pupae". What about the evolution of this power which some animals have of changing their colour to suit their surroundings? Is the power non-existent in higher animals, or if present, when would an animal be most likely to show it? Surely when it is in its most impressionable and primitive state, when according to embryologists it is about to develop and climb its own ancestral tree. But the mature and newly developing egg in viviparous animals can receive no external influence except through the body of its mother.

Let us, however, before going further get some idea of how colours usually behave towards one another on crossing. Mendel explains how on crossing two unit characters, the progeny usually shows dominance of one character over the other, in the first generation/

generation and that these characters segregate on intercrossing in the second filial ( $F_2$ ) generation. Let us take a simple case, the crossing between a black and a white sheep considering each to be homozygous to its particular colour, i.e., the black only produces gametes with determinants for black and the white only gametes with determinants for white. The result of crossing is that a "black-bearing" gamete meets a "white-bearing" gamete resulting in a "black-white" zygote which grows up into a black sheep if black be dominant, or as it is sometimes called epistatic to white. This may be represented so:-

Black sheep's gamete (B) (W) White sheep's gamete  
 (BW) - fertilised ovum or zygote which grows into a black sheep because B. is epistatic to W.

If two sheep having formula BW be bred together we would get :-

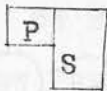
	(BW)	x	(BW)	
(BB)	(BW)	(BW)	(WW)	
pure black	impure black	impure black	pure white	

The black sheep with formula (BB) can only give/

give off black bearing gametes and so if bred with a sheep of a similar formula will always have pure black lambs. Similarly the white sheep with formula (WW) will always have pure white lambs. The black sheep with formula (BW) when interbred, giving off as they do black bearing gametes and white bearing gametes will have three black lambs to one white.

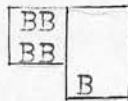
Now let us consider for a moment what takes place in such crossings as are mentioned above. We may with Weismann suppose that there is a determinant for each of these colours - probably there are more than one, but according to the recent researches of Durham (26) only one is important for the final determination of the colour of the offspring, (the basis of colour seeming to be some kind of albuminoid substance which acted on by different ferments gives different colours.)

It will be found very convenient at this stage to consider the animal as consisting of a propagative part and a somatic part, and following Dr. Berry Hart to represent them diagrammatically as follows : -

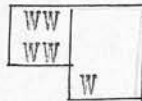


- where P. is the propagative part and S. the somatic. A pure black sheep may be represented /

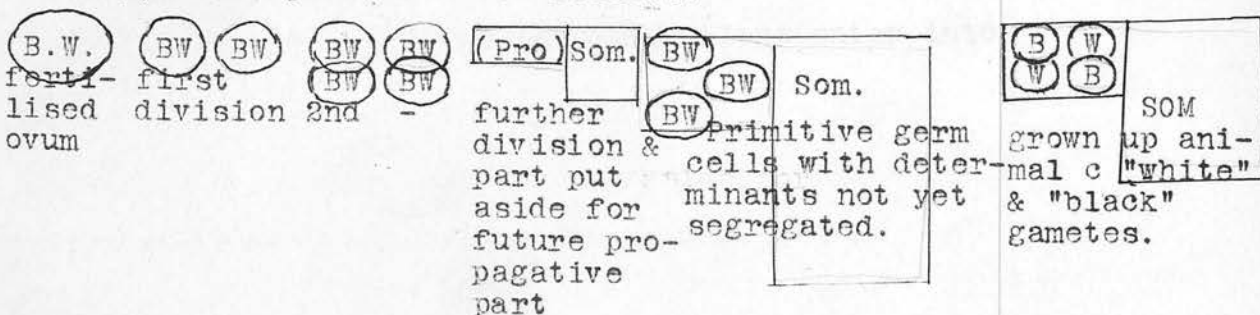
represented so -



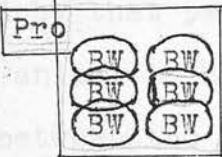
- the propagative part containing black bearing gametes and the somatic part being Black. Similarly a pure white sheep is thus represented -



Now on crossing a pure black with a pure white we get a (B) gamete meeting a (W) gamete and forming a zygote which may be represented so - (B.W). Now let us see what happens. This single fertilised ovum (B.W.) divides into two, then four, and so on, till finally one part goes to form the future propagative part of the new individual, while the other goes to form the somatic part of the same animal. We may leave the discussion of what becomes of the propagative part by saying that it contains the determinants for both, Black and White, and that these determinants in some future divisions of the cells - unknown at present - segregate so as to give gametes which are pure either for black or white. This process may roughly, be represented as follows.



The above represents what would appear to take place in the propagative part. Nothing is known, however, of how often the cells that are first set aside to form the propagative part of the new individual divide or at which division the segregation of the black and white determinants takes place. The final result, however, is in strict accordance with what takes place in Mendelian crossing. Now let us turn to what is taking place in the somatic part. After a certain number of divisions of the fertilised ovum, the greater part is set aside to form the body of the future animal. This at first consists of cells which contain the determinants for both black and white and may be represented so -



- whether any segregation occurs as these cells divide and multiply is doubtful, because if there be segregation, how are we to explain that the resultant animal is totally black in colour. I am aware that Dr. Berry Hart (27) has advanced the theory in a recent work that segregation occurs in the zygote and that, in a case similar to the one described, the determinants for black alone enter into the/

the cells that are going to form the somatic part. I cannot accept his conclusions, however, as they are contrary to those of other observers and personal experience. Take the case of crossing a red shorthorn bull and a white shorthorn cow - result - a roan colour which is the mixture of the two colours, showing surely that the determinants for each colour have found expression in the somatic part. Here one colour would seem to be dominant for some hairs and the other for others. But to return to our original case, the black and the white determinants pass into the somatic part of the animal and at some stage or the other one of these determinants gets the upper hand and the animal eventually takes on the colour determined by that particular determinant. Say the resultant animal is black in colour; - when did the struggle between the black-bearing determinants and the white-bearing take place? Was it when they first met, or when the colour was about to be formed? It would appear as if it were at the later period, as only one kind of determinant could be expected to divide and multiply if the struggle between the two sets of determinants had occurred early, whereas from what we know it appears evident that both sets of determinants pass into the somatic part and so later influence the colour of the skin. This view helps us also to understand how an animal comes to be/  
be/

be spotted in colour. For instance take a white sheep with black spots. As will be shown later white colour in sheep is sometimes dominant to black. What seems to me to take place is as follows:-

Determinants for both white and black are present in the developing embryo. White being dominant would be the only colour expressed in the young animal, but some local advantage - nutritive, nervous or whatever the real cause may be - gives the determinants for black the power to express themselves, and so we get a black spot on the otherwise white animal. I shall refer later to this view and point out that a sheep with black spots on it, especially if of large size, would seem to be heterozygous to black and white - i.e. will produce both white-bearing and black bearing gametes, and has contained in its somatic part during its development determinants for both black and white. Here then we have a struggle between two sets of determinants which it would appear can be influenced by some local condition of which we are at present in ignorance. Can we do anything to influence this struggle? Can we help the weaker to overcome the stronger? That is the point we have arrived at.

Bateson(28) says in speaking of Mendelian ratios/

ratios often not coming out according to expectations:-

"It is not impossible, nevertheless, to imagine that the output of gametes representing respectively one or other of a pair of allelomorphs may be influenced by circumstances. We have not yet any proof that such a phenomenon may occur, but the long runs of unexpected numbers which we from time to time witness in the course of Mendelian experiments are suggestive of some definite disturbance of the normal equality in the output in the two kinds of gametes" -

and suggests, if such be the case, we must search for some environmental cause. From a study of recent writings some disturbance of the nutrition of the developing cells would appear to be a possible cause of such a variation.

Is there any evidence that alteration in the nutrition causes variation? Weismann(29) suggests that germinal variations are due to fluctuation in the nutritive supply of the germ cells. "For the less well nourished determinants will grow more slowly, will fail to attain to the size and strength of their neighbours and will multiply, more slowly". He goes on to say that a slight difference in the nutritive supply/

supply is sufficient because "the determinant whose assimilative power is weakened by ever so little is continually being robbed by its neighbours of a part of the nourishment which flows towards it, and must consequently become further weakened".

In answer to the question - if the supply of food brought by the vascular fluids of the body is not always more than sufficient Weismann (30) remarks that to suppose that food is always superabundant - "seems to me much the same as if an inhabitant of the moon, looking at this earth, through an excellent telescope and clearly descrying the city of Berlin with its thronging crowds and its railways, bringing in the necessaries of life from every side, should conclude from this abundant provision that the greatest superfluity prevailed within the town and that every one of its inhabitants had as much to live upon as he could possibly require".

So here we have our greatest authority advocating small fluctuations in the nutritive supply as a cause of variation.

Recently, however, the belief in unit characters and therefore, I suppose, in specific determinants, has been undergoing a change. Many now advocate that differences in characters - for example, the/

the differences in colour of animals of the same species are more differences in quantity than in quality - that the different colours are just different stopping places of one and the same colour - producing process. If this process, which would appear to be one of ordinary metabolism or rather oxidation, stop early we get, say, yellow, and if it go on a little further, red, and then on to black.

O. Riddle (31) in an important contribution on melanin-colour formation and its relation to heredity, mentions the work done in connection with colour formation by Hlasiwetz (32) and Habermann, Bertrand, (33), Durham (34) v. Fürth & Schneider (35) Dewitz, (36) and Gessard (37) and concludes that any benzene nucleus with an attached hydroxyl can be acted upon by tyrosinase, and converted into melanin pigment. "It is of the highest importance" he says, "to see that a single chromogen acted upon by a single enzyme (so far as all chemical experience has detected) produces several colours depending upon the degree of oxidation involved". Riddle goes on to say - "The study of abnormal tyrosin metabolism and pathological pigmentation (melanin) of the human body, will illustrate the dependence of tyrosin oxidation upon somatic conditions, which may be of such a temporary intermittent, quantitative or reversible character, as to/

to preclude the possibility of accounting for them on the basis of specific independent transmissions, once for all segregated by the germ cells".

After instancing pathological conditions of melanin formation such as Addison's disease in which, according to Pforringer (38) the pigmentation differs from that produced normally only in quantity and not in origin or composition, pigmentation after nerve lesions, ochronosis and melanotic tumours, Riddle concludes that "these facts are important because they indicate that for the building of any melanin at all, the actual local conditions of the organism, or the organ, have a rôle to play that is quite out of keeping with any "once for all determination" by the shuffling of colour factors through the germs". In summing up, he remarks that "if these facts and experiments mean anything they mean that in an animal that produces melaninic colour, there exists all the machinery necessary to produce a series or scale of these colours and that what is actually produced is in several demonstrated instances dependent upon the physiological state of the organism.

The specific colour of an animal then, is an index, not of the presence in the germ, from which this/

this animal arose, of certain chromogens and specific zymogens and the absence of a wide series of others; but this specific colour means that a process with a wide range of possibilities, because of a particular physiological state and environmental conditions has struck this particular equilibrium - one and the same organism has within it all that is necessary to move that equilibrium up or down, taking the red for example, we can in the words of Tornier "force it to black or white". (Gustav Tornier (39) determined the colours of Amphibia from larval stages to old age, at will by controlling the physiological state, particularly the nutrition, of the animals.)

I have given the conclusions Riddle has arrived at somewhat fully, because they seem, if correct, to be of extreme importance. If, by alterations in the physiological state and environmental conditions of an animal, we are able to produce changes in colour, it would appear on consideration, that the subject is intimately connected with the question of maternal impressions. As I shall have to speak of this connection later on, I shall leave it in the meantime. Others, beside Riddle have investigated/

investigated the inter-relationship of different colours. Spiegler(40), for example extracted a melanin from white wool, which he considered an oxidised form of the pigment that produces the black colour in wool. This would appear to agree with Riddle's hypothesis but Gortner (41) has lately shown that Spiegler's melanin is probably not a true melanin, but a decomposition product of keratin. Chantmesse & Podwysoski (42) give as their opinion that :-  
 "le pigment cutané et oculaire de l'homme et d'un grand nombre d'animaux est la mélanine, qui produit, suisant sa dose d'accumulation plusieurs colourations (roux, chatan, brun, noir)." While the Davenports (43) in discussing skin pigmentation in man, say that - "the anatomical differences between the skin of a brunet and a blond suggest that the grades of colour may be due to more or fewer of the elements of the mosaic, and that would seem to be a discontinuous variation; but, on the other hand, since these granules increase in size and number during melanogenesis, the differences in skin colour between a negro, a mulatto, a brunet and a blond may be merely a difference in the point at which the essential melanogenetic process is stopped".

Then/

Then again Gates (44) discussing results of crossing *Oenothera nanella* and *O. biennis* and its bearing on Mendelism says:-

"That a quantitative difference between germ cells in their capacity for pigment production can behave in Mendelian fashion, showing the phenomena of dominance and segregation, is of fundamental significance in the interpretation of the nature and material basis of these phenomena". And again:-

"color inheritance in the mammals can also be most easily interpreted as a case of quantitative differences of some sort in the germ cells themselves".

It is interesting to note in this connection that Morgan (45) has adopted a quantitative interpretation of the sex-determining factors in the germ cells of insects and other organisms.

Gates (44) concludes as follows:-

"As I have shown from the evidence of these *Oenothera* hybrids and as appears from color inheritance in mammals and from other evidence, in many cases at least the difference between Mendelian germ cells must be of a simple quantitative sort, involving either a difference in the amount of certain material substances, or a difference in the energy content of certain constituents. From this point of view/

view, many instances of Mendelian behaviour are seen to be cases of quantitative inheritance".

Are we to presuppose a determinant for stopping these quantitative processes at a certain point in order to produce a given colour? Is this only a different way of looking at the action of the determinant or are we like Yves Delage (46) to reject all determinants and only postulate an extraordinary delicate and precise physico-chemical composition of the protoplasm". "L'individu développé est le produit de nombreux facteurs tous également indispensables et importants. La constitution du plasma germinatif n'est qu'un de ces facteurs. Les autres sont les tropismes et tactismes, l'excitation fonctionnelle, l'action des ingesta et egesta de la nutrition et de conditions ambiantes de tout ordre". (47) Such he gives as the causes of normal development. In regard to the causes of variation in development he gives, amongst others, alterations in alimentation (48)

"Autant l'influence des autres variations somatiques dues aux conditions de vie est faible et aléatoire autant peut-être intense celle du régime et surtout de l'alimentation. La question est très importante et mérite d'être examinée avec soin. Elle se ramène aux deux suivantes : 1° les variations/

variations dans la nature des aliments peuvent-elles modifier la composition du sang. 2° les variations dans la composition du sang peuvent-elles modifier la constitution physico-chimique des cellules et par suite leurs propriétés. Or, à ces deux questions on ne peut répondre que par l'affirmative".

So that whatever view be correct - determinants or no determinants, whether differences in characters are qualitative or quantitative, all seem agreed that fluctuations in nutrition are a probable cause of variation.

Professor E.B.Wilson says in a recent work, (49):-

"If there be a physico-chemical basis of heredity we should expect to find it capable of modification by physico-chemical agencies and so much at least is known to be the fact. Many experimenters have demonstrated the extreme susceptibility of the discharged eggs or spermatozoa to even very slight chemical and physical stimuli. We cannot doubt that they are equally sensitive to stimuli while still within the body". Certain experiments have been carried out to test this latter view.

Russo/

Russo (50) conducted a number of experiments with rabbits feeding them on lecithin and claimed to be able, by this means, to determine the kind of sex of the offspring and also to be able to entirely vitiate the Mendelian scheme of ordinary crosses. Punnett (51) however, after conducting similar experiments to Russo, though on a smaller scale, could get no effect from feeding with lecithin.

MacDougal (52), by various injections of sugar, calcium etc., into the developing ovaries of *Raimania*, one of the evening primroses, has been able to produce marked variations which breed true in subsequent generations.

Professor Tower (53), as the result of 12 years' experiments on beetles of the genus *Leptinotarsa* has been able to produce marked variations by agencies, chiefly alterations in moisture and temperature, acting on the germ cells. He produced not only changes in color markings, but also in details of structure. Sometimes all the germ cells seemed to be affected and sometimes only a fraction of them. Various changes resulted from the same temperature. Tower could not get at the reproductive organs except through the body, but it should be noted/

noted that the body of the parent was not changed and it was only at particular stages that the influence was operative. "Here then" says Thomson (54) in reviewing Tower's researches, "we have definite evidence of germinal variation evoked by environmental stimulus".

From a short and therefore necessarily, very imperfect sketch of our present day knowledge of heredity in so far as it would seem to bear on the subject of this thesis, we are led to believe that changes in the environment can produce variation.

Now let us see what bearing this has on the theory of Maternal Impressions.

The developing ovum, either before or after fertilization, being situated within the body of its mother, its environment is its mother's body, and the chief cause likely to act upon it, is some alteration in its nutritive supply. Fluctuations in the nutritive supply, as shown above is postulated by Weismann, Delage and other prominent scientists as a cause of variation and from the few experiments that have been carried out, it would appear to be an efficient cause. Can then, we may now ask, a maternal impression so influence the nutritive supply, as to cause a variation? What are the causes that produce these fluctuations in nutrition which lead to variation? Unfortunately/

Unfortunately, as yet, we do not know. Surely, however, it is desirable that experiments be conducted in order to determine if a maternal impression can possibly be one of these causes. It is only thus that we can get a decisive answer. For, arguing from what we know of physiology, it would appear quite possible for a maternal impression to be an efficient cause of variation. We know how fear - from seeing some terrible object for example, can parch the mouth and blanch the face; how the sight of something agreeable to eat will make the mouth water. But I will not enlarge further - sufficient to say that there are reflexes originating in the retina which can act on the digestive organs and on the smaller blood vessels. Is it not possible, then, that the nutrition supplied to the developing embryo may be altered either in quantity or in quality by some striking impression its mother has received. The nutritive supply might be altered in quality by reflexes acting on the digestive glands etc., etc., while it might be altered in quantity by reflexes acting on the bloodvessels of the intestines, where it is absorbed, or of the uterus where the nutriment is given over to the foetus. Enough to say that there is the possibility of alteration in the supply/

supply of nutriment to the foetus. I need only recall Weismann's view (30) given above, to those who might object to the smallness of any change that could be brought about in this way.

The above view takes cognisance only of visual impressions, but it seems possible that others of a different kind could act in the same way.

As regards the question whether a maternal impression might produce something de novo or only influence the possibilities, it would appear that the answer would depend on the view we take as to the constitution of the germplasm; but we may well leave these secondary considerations alone, till we see whether we can produce any variation at all under the influence of a maternal impression.

So that to sum up, we may say that a study of recent research work in heredity, leads one rather to expect the possibility of maternal impressions acting as a cause of variation, than otherwise, and justifies one proceeding to conduct experiments with the object of elucidating this point.

SUPPOSING THERE BE SUCH A CAUSE HOW ARE WE TO  
DEMONSTRATE IT?

---

Having noted the prevalence of the belief in maternal impressions and the importance attached to/  
to/

to a true solution of the problem, we may now pass on to discuss how best the problem may be attacked.

First of all we must get a working definition of what a maternal impression really is, and then pass on to see when and how it is supposed to act.

#### DEFINITION.

---

"Mental states, especially vivid impressions and strong emotions of a pregnant mother may so affect the unborn offspring that structural changes result, which have some correspondence with the maternal experience". Such is the definition given by J. Arthur Thomson. (55)

It has to be pointed out that those who support the maternal impression theory give the cause in one case as being due to 'fear,' and in another to 'joy'. The same emotion does not seem to be the exciting cause in all cases. Blondel remarked on this in his book, and used it as an argument against the theory. This, however, does not seem an insuperable difficulty. May not great fear and great joy have much the same action on the heart? Then again I would point out that the impression to have the best chance of success must be vivid. It is a poor argument to say, why don't sheep have blue/

blue lambs from looking at the blue sky? Let a person enter a room, papered let us say in bright red; he is struck with it at once - gets an impression, but let that same person occupy that room and in less than a week the colour of the walls has ceased to impress him. So with the sheep and the blue sky. A thing we are accustomed to, unless strongly attached to it, can scarcely be said to produce a vivid impression on our minds. On this view we can easily explain why sheep, long accustomed to a black neighbour would in breeding give no support to the theory, supposing for the moment that maternal impressions do actually play a part in the work of nature.

When, then, are we to produce this vivid impression? Is it to be before, at or after coitus? Jacob, it would appear, meant his effect to be produced at the time of coitus and among breeders at the present time a similar belief as to the time of action is held. Many, however, would also include the earliest few days in pregnancy, before any great development has taken place, as a possible time for this influence to act. Not knowing anything of the physiological process of the supposed process and wishing to give the supporters of the theory every possible/

possible chance to prove their case, it would appear to offer the best chance of success if the impression were produced at coitus and continued through the early part of pregnancy. A paternal influence has been hinted at, but we may leave this out of account at present.

#### WHAT RESULT ARE WE TO EXPECT?

---

It will be noticed in Thomson's definition that the result of the impression is supposed to have "some correspondence with the maternal experience". Now I grant that this is a correct representation of our present view of maternal impressions, but I should like to take a larger view of the subject. We want to know if there is anything at all in the theory. To be able to say that a maternal impression cannot produce "any structural change corresponding with the maternal impression", is certainly to have gone some length towards the solution of the problem as to the possible influence of maternal impressions. But the questions I should like to ask are as follow:

- (1). Can a maternal impression produce any influence at all on the unborn offspring?
- (2). If so - does the result of the impression correspond with the maternal experience?

(3)/

- (3). Is this result something that has been produced de novo? or
- (4). Is it only the result of certain possibilities being influenced?

#### CHOICE OF MATERIAL FOR EXPERIMENTS.

---

Owing to the work of the Mendelian school we are able to choose material for experimenting with, which it would have been impossible to select only a few years ago. From what we know of the results of crossing, we can predict with a considerable degree of accuracy, the probable result of mating different animals together, more especially where large numbers are used. The availability of a large number of sheep, the fact that they were the original species of animal used by Jacob, though of course much changed since then, the fact that they are timid animals and easily frightened, led me to conduct most of my experiments with them. They have even been described as the most impressionable of the lower animals.(56). Recognising the possibility that only some animals may be affected, owing to differences in their sensibility etc., it is extremely important that large/

large numbers be used in experiments.

A few experiments with rabbits, cattle and horses will also be related, and as the coat colour in rabbits especially has been very minutely investigated, we shall be the better able to understand the results obtained. Very little has been done on the heredity of colour in sheep, and it has been necessary to carry out a number of experiments to elucidate how their colour is inherited.

#### INTERPRETATION of RESULTS.

---

Just a word as to interpretation of results. It is not enough to say that the negative results of any experiments far outbalance any that can be adduced in favour of the theory. No one claims that the influence is always at work? Does it ever occur? To prove that it does not occur in a few individual cases proves little, one positive result is worth a thousand negative ones. We may not always hit on the proper time to produce the desired effect: the stimulus may not be of the proper sort, may even, if of the proper sort, be subliminal, and again there may be only some natures on which such an influence can act.

EXPERIMENTS WITH SHEEP.

---

KINDS of SHEEP.

The kinds of sheep most commonly met with in the South of Scotland are Cheviot, Border Leicester, Blackfaced or Mountain & Half Bred (that is, the cross between a cheviot ewe and a Border Leicester ram). Oxford Down & Suffolk down Rams are also used to a considerable extent.

All these different kinds of sheep have white wool and all have white hair on their faces and legs with the exception of the Blackfaced and the Oxford and Suffolk Down Rams in which the hair is black. Occasional black spots are found on the body of sheep belonging to all these different breeds but with very few exceptions they breed true to colour. There are a few totally black sheep of all the kinds mentioned, but they are comparatively rare.

Before going further, it is necessary to investigate the relation between white and black colour. How do they stand to each other in regard to Mendelism? Which is dominant and which recessive?

Davenport (57) concludes "That black wool colour in sheep behaves like a Mendelian recessive characteristic"/

characteristic" while Castle (58) describes the occasional prepotency of black over white. It is necessary to get to the root of this matter, before one begins experimenting, else one is sure to be led astray in the interpretation of the results.

EXPERIMENTS to DECIDE RELATIONSHIP of BLACK & WHITE  
WOOL COLOUR IN SHEEP.

---

I. WHITE CROSSED WITH WHITE.

---

No special experiment was needed here, as this is the farmer's common cross. I need only relate the result. The offspring of crossing two white woolled sheep is nearly always white, occasionally it may have a black spot, varying from  $\frac{1}{4}$ " to 3" or 4" in diameter. The commonest places for such black spots would appear to be about the face, or on the leg, sometimes the whole leg being black, as if the lamb were wearing a black stocking. Rarely a totally black lamb makes its appearance as a result of the above mating. The number of all lambs bred at Hundalee, from 1894 to 1908, the date at which these experiments commenced, was on an average 636 per annum, and only on one occasion was there a black lamb produced from two white woolled parents. This/

This lamb was born in March 1906, its mother being a three\_crop, half bred ewe and its sire, an Oxford Down. The ewe had had before three white lambs and all the rest of the Oxford Rams progeny had white wool. Seeing that Oxford Downs have black hair on their faces and legs, though their wool is white in colour, it naturally suggests to one that they may be prone to throw black lambs. Yet, in 4,820 cross Oxford lambs bred at Hundalee from 1894 to 1908, only the one black lamb, mentioned above, has made its appearance. A cross Oxford is the first cross between a half-bred ewe and an Oxford Down ram. In pure-bred Oxford Down flocks, however, black lambs would appear to be no rarity, as note the following letter received from Messrs Middleton & Millican, the breeders of the Oxford Down rams used in 1907-8 & 1909, in answer to an enquiry on the subject.

Kimmerghame Mains,  
DUNS.

18/5/09.

Dear Sir,

I am favoured with yours of 16th to hand yesterday.

BLACK LAMBS. I am afraid you will find less or more in every flock and it is quite possible when the breed has black faces as well as black legs that there may be a larger proportion of/

of black bodies; in our flock of over 200 pedigreed ewes, we have under half a dozen black lambs this year.

I remember a case many years ago, the first prize pen of Oxford Down Ewe lambs, purchased by a friend, when they came to have lambs, three of the five were right, the other two having black lambs. These lambs were purchased at the Royal Show.

Yours truly,

HILTON MIDDLETON.

So we may tabulate the results of crossing two white woolled sheep as follows:-

NATURE of CROSS	RESULT	REMARKS.
White x White (Halfbred x Half bred) (Chev. x Border Leicester)	White	No black appeared among 4084 lambs where both parents had also white hair on face & legs. (These were remainder of lambs born on Hundalee from 1894-1908)
White x White (Halfbred x Oxford)	Usually white	1 black in 4820 where 1 parent had white hair & the other had black hair, on face & legs.
White x White (Oxford x Oxford)	Usually white	say 4 black in 400 where both parents had black hair on face & legs.

## II. WHITE CROSSED WITH BLACK.

(where black is the female.)

Owing to the kindness of neighbouring farmers I have been able to gather the following statistics as to this cross.

B.L.=Border Leicester. H.B.= Half Bred

Ox = Oxford Down

Leicester Cross = Border Leicester x Blackfaced or Mountain.

Table/

BREED OF BLACK COLOURED EWES.	AGE	NUMBER & COLOUR OF HER LAMBS.	HAS SHE EVER HAD A WHITE LAMB?	BREED OF WHITE RAM.	NAME OF FARM.
1. Cheviot (1907)	1 crop	1 Black	No.	B.L.	Whitefield
same ewe (1908)	2 crop	1 White	Yes	B.L.	"
same ewe (1909)	3 crop	1 White & 1 Blk	Yes	B.L.	"
same ewe (1910)	4 crop	1 White & 1 Blk	Yes	B.L.	"
2 Cheviot (1908)	1 crop	1 White	Yes	B.L.	"
same ewe (1909)	2 crop	1 White & 1 blk	Yes	B.L.	"
same ewe (1910)	3 crop	1 White & 1 black	Yes	B.L.	"
same ewe (1911)	4 crop	1 White & 1 black	Yes	B.L.	"
3. Half Bred (1909)	1 crop	1 White	Yes	Ox.	Hundalee
same ewe (1910)	2 crop	1 black	Yes	H.B.	"
4. Half Bred (1908)	1 crop	2 black	No	H.B.	W. Uiston
same ewe (1909)	2 crop	1 black	No.	Ox.	"
same ewe (1910)	3 crop	2 black	No	Ox.	"
5. Half Bred (1909)	1 crop	1 White	Yes	Suffolk	Denholm Mill
6. Half Bred (1909)	1 crop	2 Black	No	H.B.	Bonjedward

BREED OF  
BLACK  
COLOURED,  
EWE.

AGE

NUMBER &  
COLOUR OF  
HER LAMBS.

HAS SHE EVER  
HAD A WHITE  
LAMB.

BREED OF WHITE  
RAM

NAME OF FARM.

7.	Half Bred (1909)	1 crop	1 black & 1 white	yes	H.B.	Bonjedward
8.	Half Bred (1909)	1 crop	1 white & 1 black	yes	Suffolk.	Humehall
9.	Half Bred (1909)	1 crop	1 white	yes	Suffolk	"
10.	Half Bred (1908)	1 crop	1 white & 1 black	yes	B.L.	Haddington
	same ewe (1909)	2 crop	2 black	yes	B.L.	Haddington(J.M.)
11.	Half Bred (1909)	1 crop	1 white & 1 black	yes	B.L.	"
12.	Half Bred (1909)	1 crop	2 black	No	H.B.	Swinnie
13.	Leicester Cross (1908)	1 crop	1 white	yes	H.B.	"
14.	Same ewe (1909)	2 crop	2 white	yes	H.B.	"
	Half Bred (1908)	1 crop	1 white	yes	B.L.	Cleuchhead
	same ewe (1909)	2 crop	1 white & 1 black	yes	B.L.	"
15.	Half Bred (1909)	2 crop	2 black	No.	H.B.	Ashtrees
16.	Half Bred (1908)	2 crop	1 white & 1 black	yes	Ox.	"
	same ewe (1909)	3 crop	1 white & 1 black	yes	Ox	"
17.	Half Bred (1909)	1 crop	2 white	yes	Ox	Howden
18.	Half Bred (1909)	2 crop	2 black	No answer	Ox	"

BREED OF  
BLACK  
COLOURED  
EWE.

AGE

NUMBER &  
COLOUR OF  
HER LAMBS

HAS SHE EVER  
HAD A WHITE  
LAMB.

BREED OF WHITE  
RAM.

NAME OF FARM.

19.	Half Bred (1909)	3 crop	3 black	no answer	Ox	Howden
20.	Half Bred (1907)	1 crop	2 black	No	E.L.	Nisbet
	same ewe (1908)	2 crop	2 black	No.	E.L.	"
	same ewe (1909)	3 crop	2 black	No.	E.L.	"
21.	Half Bred (1907)	1 crop	1 white & 1 black	Yes	E.L.	"
	same ewe (1908)	2 crop	1 white & 1 black	Yes	B.L.	"
	same ewe (1909)	3 crop	1 white & 1 black	Yes	B.L.	"
22.	Half Bred (1908)	2 crop	1 white & 1 black	Yes	B.L.	"
23.	Half Bred (1909)	1 crop	1 black	No.	B.L.	"
24.	Half Bred (1909)	1 crop	1 black	No.	B.L.	"
25.	Half Bred (1909)	1 crop	2 white	Yes	B.L.	"
26.	Half Bred (1909)	1 crop	1 black	No.	B.L.	"
27.	Half Bred (1908)	2 crop	1 white	Yes	H.E.	Mounthooly
28.	same ewe (1909)	3 crop	2 black	Yes	H.B.	"
	Half Bred (1909)	1 crop	2 black	No	H.B.	"

From the above it will be seen that twenty-eight black woolled ewes have produced seventy-nine lambs, of which 49 are black and 30 white. So we again tabulate results as follows:-

Nature of Cross	Result	Remarks.
Black ewe X White ram	Black 49 White 30	White lambs bred off Oxford or Suffolk Rams showed cross OX or cross Suffolk markings on face & legs.

### III. WHITE CROSSED WITH BLACK

where black is the male.

Two sets of experiments were conducted with this cross. First where the black ram was the progeny of a black ewe and a white ram and second where the black ram was the progeny of two white parents.

(A.) Cross between white woolled halfbred ewes and a black ram, the progeny of a black cheviot ewe and a Border Leicester ram.

NO./

No. of Ewe.	Result	Remarks.
1.	1 black	A few white spots on crown of head.
2.	1 white	
3.	1 black & 1 white	Black lamb has a white cross on face, while white lamb has a few brown spots on legs.
4.	1 black & 1 white	Black lamb has white blotch on face.
5.	1 white	Died shortly after birth
6.	1 white	
7.	1 white	Black spot 4" in diameter on right hip
8.	2 black	Both have a little white on face and tip of tail.

The above may be tabulated for the sake of uniformity so:-

Nature of Cross	Results		Remarks.
	Black	White	
White ewes x Black ram	5	6	Both parents being halfbreds all the lambs were typical except as regards colour.

B./

(B.) Cross between white-wooled halfbred ewes and a black ram - the progeny of a white halfbred ewe and a white woolled Oxford Down Ram.

No. of Ewe.	Result	Remarks.
1.	1 White	Brown patches on legs, and a very little brown on ears.
2.	2 White	
3.	1 White	A few brown patches on head and legs.
4.	2 White	Slight brownish markings on legs.
5.	1 White	Very slight brown points.
6.	1 White	Brownish points.
7.	1 White	Brownish points.
8.	No lamb.	

Again we may represent the above as follows:-

Nature of Cross	Result		Remarks.
	Black	White	
White ewes x black ram	nil	9	The ram being a cross Oxford explains the brown markings on lambs. It was found later that some grew wool on forehead, like Oxford sheep while others didn't. I had grey face, the others white.

#### IV. BLACK CROSSED WITH BLACK.

Where both the ewes and the ram had one black parent and one white.

No. of Ewe.	Result	Remarks.
1.	2 black lambs	White blotches on foreheads and white tips to tails.
2.	1 black lamb	White blotch on forehead.
1.	No lamb.	
Black x Black	3 black	Otherwise typical halfbred sheep.

#### V. BLACK CROSSED WITH BLACK.

Where the ewe had two white parents and the black ram one white parent and one black.

Unfortunately the number of sheep at my disposal for this cross was small and more unfortunately no lambs were born.

#### VI. WHITE CROSSED WITH WHITE

Where the white were the lambs born as a result of experiments III.B., that is their mothers were white and their sire, though black, was descended off two white parents.

No. of Ewe.	Result	Remarks.
1.	1 Black	Brownish ear tips, and brown colour over back.
2.	1 Black	Brownish-black on face legs and back.
3.	1 White	
4.	1 White	Brownish colour on legs.
5.	No lamb.	

Nature of Cross	Result	Remarks.
White X White	Black 2	White 2
		The ewes & rams used in this cross being both descended of a cross Oxford ram, probably explains the brown markings on lambs.

### VII. BLACK CROSSED WITH BLACK

Where both ewes and ram were descended off white parents.

Owing to the rarity, 1 in 4,820, as mentioned above, of black lambs being bred off white parents except in such a case as recorded in Experiment VI., I was unable to try this experiment. But as will be seen later, the expected result would be, that black lambs would always appear.

Discussion/

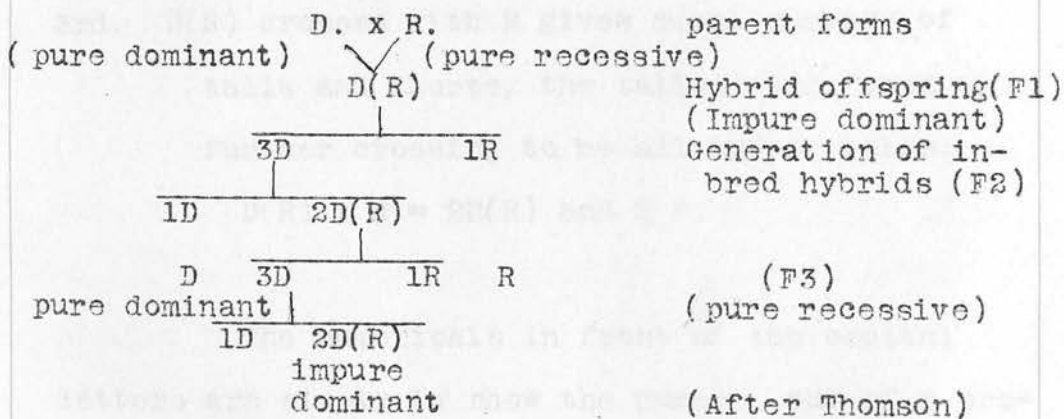
## DISCUSSION of RESULTS of ABOVE EXPERIMENTS.

How are we to explain the above results?

From a casual glance it is obvious that black and white don't always behave towards each other in the same way. In Experiment No.2, we have more blacks than whites as a result of our crossing. In Experiment No.III A, we have nearly equal numbers of black and white, while in Experiment No.III.B., we have only white lambs. To start with I would point out the great danger there is in dealing with too few numbers, from which one has to be careful in deducing any definite conclusions. In order to thoroughly understand the deductions drawn from these experiments it is necessary to describe in a few words the elements of Mendelism.

Mendel, in crossing plants, found that of two contrasted characters, say length and shortness of stalk, one was dominant and the other recessive, that is, the progeny of a tall and a short plant was tall, because tallness was dominant to shortness although it (the progeny) still contained the element for shortness in its constitution, on intercrossing members of this first cross (the cross between tall and short individuals) that is members of/

of the first filial (F1) generation, it was found that out of every four of their offspring (F2) or second filial generation, three were tall and one short. On further crossing members of the F2 generation it was found that one of these three tall was pure to tallness, the other two were found to be impure to tallness, that is gave on an average when intercrossed three tall to one short, while the one short of the F2 generation was found to breed true to shortness. This may be diagrammatically represented as follows - (It makes no difference whether the male or female is dominant).



D(R) is a tall plant indistinguishable from D. except by breeding, the dominance of the stronger character completely swamping the weaker. This would not appear to be always the case as from personal experience I have known many cases where D(R) was quite distinguishable from D.

I need only emphasise now three points.

1st. D. crossed with D(R) gives all talls which on further crossing are found to consist of half pure talls and half impure talls.

$D \times D(R) = 2 D.$  and  $2D(R)$

2nd. D(R) crossed with D(R) gives three talls to one short the talls being found on further crossing to consist of one pure tall and two impure talls.

$D(R) \times D(R) = 1 D,$   $2D(R)$  and  $1 R.$

3rd. D(R) crossed with R gives equal numbers of talls and shorts, the talls being found on further crossing to be all impure talls.

$D(R) \times R = 2D(R)$  and  $2 R.$

The numericals in front of the capital letters are simply to show the number, out of a progeny of four, of talls, impure talls and shorts. The results might equally well have been given in per centages.

We are now in a position to explain our experiments with wool colour.

From a careful consideration of the experiments carried out, it would appear that black is/

is usually dominant to white, but that a pure dominant black sheep is rare. Nearly all the black sheep that one sees, seem to be impure dominants and this is not to be wondered at, considering that two black sheep are rarely, if ever, bred together in the ordinary course of events. Nearly all black sheep have had one white parent. Taking then, black sheep as impure dominants  $D(R)$  and white sheep as pure recessives  $R$ ., let us see if this explanation agrees with results of our experiments.

White crossed with black, no matter which parent is black, should give equal numbers of black and white:-  $D(R) \times R = 2D(R)$  and  $2 R$ .

The numbers resulting from Experiment No. IIIA, though small are nearly equal, but in Experiment No. II there are more blacks than whites, 49 to 30. (The result of Experiment No. III.B. I shall explain immediately)

There are three possible explanations why the blacks and whites are not equal in number in Expt.No. II.

- 1st. We may be dealing with too few numbers.
- 2nd. It is just possible that some of the black ewes may have been pure dominants; note the results of Ewes No.4, 15 & 20. These are said never to have had a white lamb. If pure dominants they should always give black. If this be the true explanation then we have

to subtract 13 from our 49 black lambs leaving 36 black to 30 white which are practically equal numbers of white and black.

3rd. It will be shown later that white sheep occasionally carry a recessive black element constitution. Is it not possible then, that it is the presence in a flock of some of these white sheep carrying latent black, that tends on crossing white and black sheep to lead to a preponderance in number of black lambs over white instead of the equality of numbers which we expect?

The relationship between dominant black and recessive black has not yet been made out, unfortunately Experiment No.V was a failure, but it is just possible that a cross between D(R), where D. is dominant black and D(R) where R is recessive black might give rise to such ewes as No.4, 15 & 20 which on breeding appear to be pure dominants. The only other way pure dominant blacks could appear is by breeding D(R)x D(R), two impure dominant blacks which would give one pure dominant in every four.

Of course there is the probability that Ewes No.4 15 & 20 are impure dominants which, if still/

still further bred from, might produce a white lamb, and that again we may have been dealing with too few numbers.

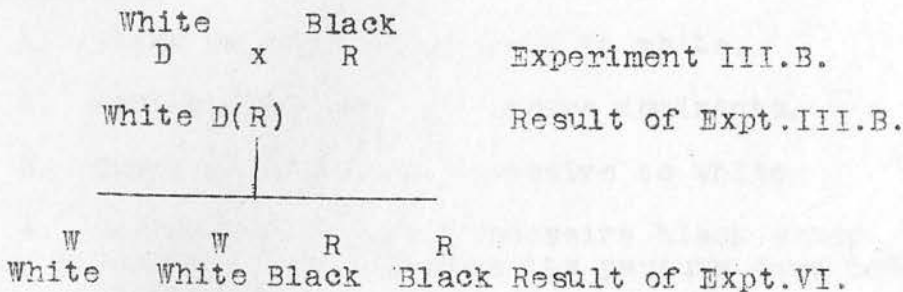
So far as the result of one experiment goes, an equally good explanation of why we get equal numbers of black and white, as a result of crossing black and white parents, would be to consider white as an impure dominant and black as recessive. On crossing, however, white with white, that is  $D(R) \times D(R)$  we should expect one in every four to be black and we have seen from Experiment No. I. that we only get one black in about 4,000; so we are practically certain that the ordinary black sheep is an impure dominant with black dominant to white.

Occasionally, however, it would appear that black is recessive to white and this would explain the rare occurrence of a black sheep in a white flock. In this case most of the white are pure dominants to this particular kind of black, and there are only a few white sheep, impure dominants. The scarcity of these impure dominants, the small chance of their mating together, and the expected proportion of only one black in every four lambs, would explain why we so seldom see white crossed with white giving black. It will be seen from Experiment I. that these impure dominants are extremely/

extremely rare, if they ever occur, amongst sheep with both white wool and white hair, but that where the hair on the face and legs is black, they are more common.

This then, is the explanation of the one black lamb in 4,820. A somewhat similar explanation will be seen later in connection with the appearance of red coloured calves in a black Aberdeen Angus herd of cattle.

We can now explain the result of Experiment III.B.: the Black Ram in this case being a recessive when bred with dominant whites gave only whites. These whites when intercrossed in Experiment VI. gave black and white. The theoretical result should have been one black to three whites, but the numbers being small it was impossible to get the exact figures. We may represent Experiments No. III B. & VI. diagrammatically as follows:



Black crossed with black in Experiment IV. where both/

both blacks are D(R), the black colour being dominant in this case, should give three blacks to one white. The three blacks have been produced but owing to scarcity of numbers the white has not yet arrived.

I would point out in connection with this cross the prevalence of white markings on the heads of the progeny. This mark shows, I think, evidence of their being impure dominants. They have both white and black bearing determinants in their body, and the white owing to some local advantage have been able to assert themselves and determine the white colour on the heads. As has been said before there is not always complete dominance of one colour over the other and I shall have to point out later, in connection with the experiments on maternal impressions that a large black spot on a sheep is very suggestive of its being an impure dominant, with black recessive.

#### TO SUM UP.

1. Black is usually dominant to white.
2. Most black sheep are impure dominants.
3. Black is sometimes recessive to white.
4. Occasionally a pure recessive black sheep appears in which case its parents have both been white.
5. Most white sheep are pure as to whiteness, that is they are pure recessives to dominant black and pure dominants to recessive black.
6. There are a few impure dominant white sheep.

EXPERIMENTS with SHEEP in MATERNAL IMPRESSIONS.

---

Having now arrived at some conclusions as to the manner coatcolour is inherited in sheep, we are in a position to understand the experiments carried out to show the extent of the influence which the maternal imagination has, in such inheritance.

It will be seen from the experiments that I have used a black colour in nearly every case to produce the impression. My reasons for choosing this colour were chiefly, that it was easily procured, that sheep could be impressed by this colour, and that, it is the colour which, amongst breeders, is chiefly said to be the exciting cause of a maternal impression, while again it obviates the necessity of carrying out a series of experiments to determine the colour perception of sheep. There is no doubt but that they can appreciate black colour; so it will depend upon our results positive or negative, whether we require to proceed in determining the perception of sheep in regard to different colours or not.

EXPERIMENT No. I. 175 H.B. ewes & 2 Oxford Down Rams.

The ewes are all white, one and two crop and mostly out of Cheviot ewes by Border Leicester Rams/

Rams, while the rams are 2 & 3 years old respectively, typical Oxfords, bought from Kimmerghame Mains. The younger ram has a black patch 3" in diameter behind left ear.

On 14th October 1908, these ewes and rams were mated together, on 21st October 1908 forty-one ewes had been tupped and these were marked with red on near kidney.

On 20th October 1908 a black ewe was put beside these ewes and rams, by which time a total of 68 had been tupped. The white ewes were evidently afraid of the black ewe as they ran from her, looking back as they ran. Later they showed their curiosity by coming up and smelling her. Some white ewes evidently thought she was another Oxford Ram, as they left the ram they were with and came running to her; but after smelling her did not stay long in her company.

On October 26th - black ewe tupped by 3 yearold Oxford ram. She was thus with one of the tups, while ewes were still unaccustomed to her and had every chance of influencing the other ewes, as they approached the ram. Unfortunately they were tupping slowly.

On/

On 27th October ewes still showing their curiosity by coming up and smelling her.

On 28th October, 39 excluding the black were marked with red on near shoulder as being tupped during the second week. 12, therefore had been tupped since the black was put amongst them.

30th October. Black ewe taken out to-day - total tupped 101 - giving a total of 33 tupped while black ewe was among them. White ewes now take no notice of her.

11th Novr. This lot was to-day mixed with lot No.III. and the black ewe put among them. Black ewe will now be with them till lambing time.

NOTE.I. The Black ewe is one and a half years old, perfectly black except a few small white spots on face and a very slight brownish tinge on end of wool over back and sides. This is the only black sheep on the farm at present.

NOTE II. None of the ewes in above experiment has ever had a black lamb and none had seen a black sheep for a year previous to October 1908.

#### RESULT.

15th March 1909. A white ewe lambed this afternoon marked with red on near kidney (1st week) one black lamb and one white lamb, both cross- oxfords.

26th/

26th March 1909. A white ewe lambed this afternoon marked red on far shoulder(3rd week) one black lamb and one white lamb - both males and cross-oxfords.

26th March 1909. Black ewe lambed to-day a white single ewe lamb.

All other ewes had white lambs, 292 in number with cross oxford markings on face and legs, that is grey face and legs and tuft of wool on forehead.

EXPERIMENT NO.II. 122 H.B.gimmers ( $1\frac{1}{2}$  years old)  
& 2 H.B.Rams.

Gimmers, that is females that have never had a lamb, are the same breed as ewes. Rams were got from Meigle and Alnham Castle.

21st October 1908. The above sheep were mated together to-day. Black ewe is with them at time of mating. She has been with them for a year and they are all thoroughly acquainted with her.

25th October. 30 of above white sheep are tupp'd. Black ewe taken out from among them.

28th October. 55 of above tupp'd and marked with red on near shoulder.

The above lot of ewes never saw the black ewe again till 25th December 1908

RESULT - No black lambs.

EXPERIMENT NO.III. 25 H.B.ewes and 6 Cheviot  
gimmers and 1 H.B.Ram.

All these ewes were tupped with the exception of two when they were mixed with lot I. which contained the black ewe.

RESULT. No black lambs.

EXPERIMENT IV. 159 Cheviot ewes and gimmers and  
3 Border Leicester rams.

These sheep were mated on 28th October and began to tup very fast. They had no chance of seeing a black sheep since March 1908.

30th October 1908. Black ewe put amongst above at 2.p.m. Ewes not afraid, but showed their curiosity by coming up and smelling her. Black ewe went forward to one of the rams which was surrounded by ewes but none were actually tupped while the black ewe was close to the ram.

29 Cheviots had been tupped up to the time black ewe was put amongst them.

4th Novr.1908. 50 marked to-day for first week of Cheviots.

11th Novr. Black ewe taken out to-day, having been in almost a fortnight. 60 marked to-day for second week of Cheviots.

RESULT. No black lambs.

EXPERIMENT/

EXPERIMENT V. 40 Cheviot gimmers and 2 Border  
Leicester rams.

28th October. The above sheep were mated to-day at midday, on farm of Whitefield. This evening two black cheviot ewes, which they had never seen before, were put beside them. They were not much afraid of black ewes, which went a good deal by themselves. Whenever black ewes approached the white, the latter ran away but afterwards came up and smelled them. Only two tugged when black ewes put in the lot.

RESULT. No white ewes had black lambs. Each of the black ewes had a black and a white lamb.

EXPERIMENT VI. 8 white ewes and a black ram.

These are the sheep that were used in Experiment III. B. mentioned previously in connection with colour heredity in sheep.

26th October 1909. Mated these eight ewes and black ram to-day. Ewes which had never previously seen a black sheep, were tremendously afraid of the ram and would not allow him to come near them. In fact whenever the ram approached they took to their heels as fast as they could.

30th October. Ewes beginning to get accustomed to ram though they still move off when he comes near them.

2nd/

2nd November. 4 ewes tupped up till today.

11th November. 8 ewes now tupped and ram taken out. Special mark put on ewes which were then mixed with a bigger lot.

RESULT. 9 white lambs, one of ewes being yeld.

Some of lambs had brownish markings on legs and head, but this is explained by the black ram being got by an Oxford Ram. In fact this black ram was the lamb born on March 15th 1909, mentioned in Experiment I.

EXPERIMENT VII. 90 H.B. ewes and Oxford Ram. The Oxford Ram has black spot behind left ear. and is the same as was used in Experiment I. last year.

12th October 1909. Above sheep mated together to-day.

26th October. Two black rams were driven through the above lot of sheep. Ewes ran forward and smelled them. No ewes were tupped, as I was present myself and the rams were in the field only ten minutes altogether, being on their way to another field and within five yards of the shepherd all the time.

27th October. Ewes and ram were taken to a different field. Here they had an opportunity of seeing 2 black sheep grazing in the adjoining field.

28th/

NOTE. 28th October. Saw a white ewe, with forebit in far ear and big black spot at root of near ear tupp'd while looking through a wire fence at a black lamb which was in adjoining field. The ewe was nearly touching the lamb with her nose.

31st October. 62 of above ewes tupp'd up to to-day. Oxford ram taken out with these 62 ewes and put in different field. Twenty untupp'd white ewes added to remainder and a H.B. ram put beside them.

2nd November. Ewes tupp'ing slowly. Have every opportunity of seeing black rams in adjoining field, which in case of accidents, have been securely hobbled.

11th November. One of black rams has got beside white ewes, but being hobbled is prevented from doing any damage.

RESULT. 27th March 1910. White half bred ewe had pair to-day, one white and one black, both cross oxfords.

NOTE. This ewe was one of the sixty-two mentioned under date 31st October.

27th March 1910. White halfbred ewe had pair to-day one white and one "brocklie" coloured, both lambs except for colour were typical half breds.

NOTE/

NOTE. This was one of the twenty ewes added on 31st October.

A "brocklie" coloured sheep has white wool on back and sides while hair on legs and wool on belly, chest and slightly up the hips is black. Face is a dun colour with black markings over eyes and on jaw.

This was the first "brocklie" coloured lamb ever bred at Hundalee and strangely enough at the time, there was a "brocklie" coloured cheviot on the place, the first we had ever had; received as a present the year before.

All the other ewes had white lambs; there being 105 cross oxfords to the one black mentioned above.

The ewe mentioned under date 28th October, had two white lambs.

EXPERIMENT VIII. 189 ewes and 2 H.B. rams. Amongst ewes is black ewe which, however they are quite accustomed to and of which they take no notice.

26th October 1909. Ewes and rams mated to-day.

6th November. 1909. Black ewe taken out all tugged except twenty-seven.

RESULT. No black lamb.

EXPERIMENT/

EXPERIMENT IX. 146 gimmers & 3 H.B.rams.

2nd Novr.1909. Above gimmers and rams mated to-day.

6th November 1909. 17 of above already tupp'd. Black ewe put beside them. White ewes not much afraid, ran up and smelled black ewe.

9th Novr. 32 gimmers tupp'd, that is 15 since black ewe was put beside them.

12th Novr. Black ewe taken out.

RESULT. No black lambs: all the lambs being white and typical half breds.

EXPERIMENT X. 35 Cheviot gimmers and Border Leicester Ram.

4th Novr. 1909. Above sheep mated to-day and in evening a black Cheviot ewe was put beside them. They had never seen a black sheep before, yet they paid very little attention to her.

11th Novr. Black ewe taken out, 19 of gimmers tupp'd and marked.

RESULT. No black lambs.

EXPERIMENT XI. 164 H.B.gimmers & 3 H.B.rams.

25th October 1910. Above sheep mated together. Owing to being recently clipped one of the rams has a brown coloured sack tied on to his back.

1st Novr. 55 tupp'd and marked. A large

black cloth was tied over one of the rams, covering his back completely and only leaving his head legs and tail uncovered. Ewes very much afraid of him when first he ran amongst them: later on they came up and smelled him all over. Gimmer with black leg was noticed to be going with this ram in the evening.

4th Novr. Black cover taken off. Ewes quite accustomed to it. Number tupp'd since it was put on 34.

RESULT. No black lambs, all typical halfbreds and none with any marked black spots on them.

EXPERIMENT XII. 71 Cheviot Ewes and 2 Border Leicester Rams.

28th October 1910. Above sheep mated together.

7th Novr. 34 tupp'd and marked.

10th Novr. Put a black cover over one of the rams, similar to previous experiment. Ewes very much afraid and would not let ram approach them.

11th Novr. Put other 14 untupp'd ewes with above lot, they also were very much afraid.

15th Novr. Ewes now accustomed to black on ram's back.

20th/

20th Novr. Black cover taken off ram.

RESULT. All the above ewes, except three which were yeld, had white lambs, only one lamb had a small black mark on its right fore leg.

#### DISCUSSION OF RESULTS.

---

From an examination of the results, obtained in the experiments just recorded, it would appear at first sight that if the maternal imagination is ever at work, it acts but rarely. But have we given it every chance of demonstrating its influence? I think we have. We have presented to the eye of the mother in some cases before, in some after, and in a few at the time of coitus, a visual impression which according to all the supporters of the theory of maternal impressions should be sufficient to influence the colour of the progeny. It might seem as if the stimulus were not strong enough to produce any effect and yet it is just such an exciting cause, as we have used in these experiments, as is nearly always amongst breeders at least, said to be sufficient to produce the desired result.

What conclusions then are we to draw?

In/

In ten out of the twelve experiments no obvious result of the maternal impression can be noted.

In the other two experiments Nos. I. & VII. we have results which it is necessary to investigate very carefully.

Let us first of all state the facts.

CASE NO. I.

On 15th March 1909, a white ewe had two lambs, one white and one black. Their sire was an Oxford Down Ram the ewe being marked on near kidney must have been tupped before black ewe was put beside her on 25th October 1908 in fact must have been tupped at least four days before this. In 1909, this white ewe had two white cross Oxford lambs, and in 1907 one white halfbred lamb. She was sold in autumn of 1909.

CASE NO. II.

On 26th March 1909, another white ewe had two lambs one white and one black, sire also an Oxford Down, this ewe being marked on far shoulder must have been tupped either during the last two days the black ewe was with her or in the subsequent five after the black ewe was taken out. In 1908 this ewe had two white halfbred lambs to a halfbred ram, while last year 1910, she had two white cross Oxford lambs.

CASE/

CASE NO. III.

On 27th March 1910 a white ewe had two lambs, one white and one black, sire Oxford Down. This ewe one of 62 was known by the shepherd to have been tupped while she had the chance of seeing two black sheep in adjoining field. In 1909 this ewe had 2 white halfbred lambs. and in 1911 two halfbred white lambs.

CASE NO. IV.

On 27th March 1910 a white ewe had two lambs, one white and the other "brocklie". It was possible for this ewe to see 2 black sheep while being tupped, but impossible for her to have seen the "brocklie" coloured ewe till three months after. This ewe had one white halfbred lamb in 1909 and a pair of white half bred lambs in 1911.

So much for the facts of the case. We may dismiss the last result recorded, in which the "brocklie" coloured lamb appeared. Undoubtedly there could be no maternal impression here, owing to the length pregnancy had advanced before the possibility occurred of an impression being received.

As regards the other three cases in which black lambs appeared, three important points strike/

strike one; first that each black lamb was a twin, the other lamb being white, and second, that their sire was an Oxford, third, that the impression if any, was received at different times in pregnancy. No black lambs resulted from the matings where both parents had white hair on faces and legs and also white wool. The fact of their being twins, is no great evidence against the maternal impression theory for has not Power in his experiments on beetles shown that sometimes only certain ova are influenced by outside agencies, while others remain uninfluenced. The strongest point against the black colour being due to a maternal impression is, that it only occurred in the cross where one parent had black hair on face and legs, in a cross in which we know from previous experiments, black lambs are liable to occur, though only in the proportion of something like one in 4,000. Here, however, we have 2 black lambs in 292 in Experiment I. and one black lamb in 105 in Experiment VII. Is it possible that a maternal impression has influenced this result? It would appear from the results of the other experiments that a maternal impression has no influence in producing anything de novo. We know from the experiments on colour heredity that a black lamb never makes its appearance/

appearance, at least as far as one experience goes, in crosses where the hair as well as the wool is white and in such crosses we find that apparently the maternal imagination has no influence. But can this occult power influence the possibilities of a certain cross? If black lambs may appear in a particular cross can it increase their number? Can it influence the output of particular colour-bearing gametes or when different colour bearing gametes unite to form a zygote can it influence the struggle that occurs in which one unit character gets the upper hand and dominates or determines the colour of the resultant animal? This it is difficult to decide and most elaborate statistics would be necessary to prove it.

As regards the third point, in Case I., the ewe must have received the impression when she was nearly a week pregnant. In Case II. the ewe received it probably before she was pregnant as she was quite accustomed to the black ewe before being tupped, while in Case III. the ewe probably received the impression about the very beginning of pregnancy. Not knowing anything of the physiology of the "modus operandi" of maternal impressions we are unable to say whether the above discrepancies in the time of receiving the impression support the theory or otherwise.

So far then, we see nothing against the maternal/

maternal impression theory being a possible cause of the appearance of these black lambs.

There is, however, another possible explanation which being in accordance with known facts is probably the true one. The explanation is Mendelian. We have seen that recessive black is apt to appear from an Oxford cross and more commonly when pure Oxfords are bred together. This naturally suggests that some Oxford rams are impure dominants, that is, though white in colour, they carry black as a recessive and if mated with another impure dominant would give one black in every four lambs. Now, I would suggest that the ram with the large black spot 3" in diameter, behind his left ear, is an impure dominant and moreover, that the black spot is a sign of his being such. Bred with pure white ewes he should always give white lambs, but bred with ewes that are also impure dominants he would give one black lamb in every four. It will be seen from experiments on colour heredity that there are possibly a few impure dominant whites and such I would consider the ewes mentioned in Cases I., II., & III. It will be seen from the previous and subsequent record of these ewes that they have in other years, only had white lambs, but this is in accordance with/

with expectation. Unfortunately the long period of pregnancy, their short lives, the fact that they may have only one or two lambs at a birth and the expense involved, prevented me from carrying out experiments to see definitely whether the Oxford Ram and the ewes in question were actually impure dominants. But fortunately, when one is dealing with a large number of sheep one is able to arrive at fairly accurate conclusions.

TO SUM UP.

- I. A Maternal impression seems to have no power among sheep to produce anything de novo at least.
- II. There is a possibility that it may influence the possible results of a certain cross.
- III. In all probability maternal impressions have no influence whatever on the inheritance of colour in sheep and any unexpected results can probably be explained in the light of Mendelism.

CATTLE/

## CATTLE.

KINDS of CATTLE.

The chief breeds of cattle in the South of Scotland are Shorthorn, Aberdeen Angus, Ayrshire and Galloways. I do not propose to say anything regarding the Ayrshires except that they vary greatly in colour and only this in connection with the Galloways that Barrington & Pearson (59) have shown that the result of crossing black galloway cows and white shorthorn bulls is not always in accord with Mendel's law. The Hybrid is usually blue grey but red and roan also appear as well as white with black markings. One has a splendid example in the above how easily one could be misled in trying experiments in maternal impressions, before first of all getting a knowledge of the colour inheritance on crossing. It will be seen that we cannot place implicit faith in Mendelism, in the manner it is at present understood, as applied to colour in cattle. This is equally true, as seen from the results of crossing pure shorthorns of different colours. Shorthorns are described as of the following colours:-

red, red-with-little-white, red-&-white, roan and white.

Roughly/

Roughly speaking red crossed with white gives roan and when roans are intercrossed we get, again, roughly, the proportion 1 red, 2 roans and 1 white as if following Mendel's law.

D	x	R	
red		white	
	DR	roan	
-----			
D	DR	DR	R
red	roan	roan	white

Here there is not complete dominance of red, hence roan colour.

But there are many exceptions to the above and Wilson (60) after a careful study of the history of the breed and a demonstration of how the Mendelian characters come out, has to add a paragraph "Explanation of Discrepancies". Red crossed with red has been known to give rise to all the different colours while white crossed with white, is recorded by Pearson, as producing in 91 cases, 86 white, 4 roans and 1 red.

From the above short statement of what is known about the colour inheritance in shorthorns, at once the difficulty is recognised of carrying out any experiments in regard to the influence of maternal impressions. It is practically impossible to secure the number of say, white cows and white bulls and see, whether they, as a result of a maternal impression/

impression, can be made to produce young of a red colour in larger proportion than red normally occurs. A few isolated experiments would be of little use. A number of instances of the supposed influence of the maternal imagination, on colour inheritance in cattle are recorded by Harvey (61) & Thomson (62) related the following case, which I shall give owing to the great prominence the owner of the cattle has in the shorthorn world of to-day - viz:- Mr Duthie of Collynie, who conducted the experiment.

"A light roan cow of very good quality was served repeatedly by a crack light roan bull. She had three or four very good white calves. But a roan calf was much desired, and the following experiment was tried. She was served by the roan bull, and at the same time she had in view - over the wall - a red yearling, which was afterwards put into the next stall. The cow eventually gave birth to a red roan heifer calf of great beauty. This is not an isolated case. From a pure white bull and a white cow a fine red roan calf was produced, and this was attributed to the fact that the white cow was continually accompanied by a red cow".

Other examples of similar experiences could be given where in some cases the cow was blindfolded and after the sire had gone, the bandages were removed/

removed and an animal of the desired colour was brought to be a companion to her.

But let these suffice.

The only experiment I have carried out was as follows:-

9th April 1909. A white cow was mated with a roan bull to-day, in the presence of a pure black coloured bullock. The bullock was well in sight of the cow all the time and she was quite unaccustomed to see black cattle. Cow & bullock would be together for about ten minutes and were then separated.

11th January 1910. White cow had a white heifer calf this morning.

#### DISCUSSION.

---

As mentioned above a few isolated cases prove little if anything. The explanation of the results obtained by Mr Duthie is obvious. In the first case two roans were practically bound at some time or other to produce a roan coloured calf, the chances being that one in every two calves from such a cross would be a roan. As for the white crossed with white giving a red roan, Pearson mentions four occurring in 91 such crosses. How then can we come to/

to any definite conclusion? The simplest and easiest explanation is Mendelian yet we must not be too dogmatic. As mentioned in reviewing the experiments with sheep, there is just the possibility that the maternal imagination is playing a part and, where in a certain cross one, two or even three possible colours may arise, it may tend to so influence the manifestation of these colours that one colour, the colour which produced the impression, is more often produced than the others.

Large numbers and carefully worked out statistics would be necessary to settle this point. I think on the whole, as far as our present knowledge goes, that the Mendelian explanation is the true one.

ABERDEEN ANGUS: This is a black polled breed of cattle and it was this breed that was used in the only experiment in maternal impressions of which I have been able to find any record. It is well known that though these cattle usually throw black calves, a small percentage appear with white patches or may even be red in colour. What this percentage is, is not definitely known, but an idea will be gained from a perusal of the following cases.

Many Aberdeen Angus breeders, strong believers/

believers in the effect of the maternal imagination, believe that by taking proper precautions, they can prevent the appearance of these calves of "broken colour" as they are called.

Professor Wallace (63) related how McCombie of Tillyfour, one of the pioneers in this breed of cattle, succeeded in preventing his black polled Angus cows from breeding red or broken coloured calves, by putting up a high black fence round the paddock in which he mated them as they came in season, thus preventing them seeing the parti-coloured cattle of his neighbours.

Here again we have the idea cropping up, that if two things are possible from a certain mating, the maternal imagination can be used to influence the result, causing a much greater number of the young, than normally occurs, to be of the desired colour. The same objection arises here as previously; want of sufficient statistics to prove such a proposition.

I shall now give a record of the experiment in maternal impressions, related by Professor Wallace (63) and carried out by Henry Lindsay, bailiff, Earl of Strathmore's home farm Glamis. The experiment was conducted with 30 cows of the most highly prized/

prized strains of blood.

"The cows with bull-calves were annually separated from the cows with heifer-calves when turned out in May, and the herd was thus grazed in two divisions of about equal numbers (which for convenience we shall term A. & B.) It was observed for a number of years that about 20% of the calves produced by the cows of division B. were "badly marked" in colour viz:- red or black and white - while the colour of the calves of division A. were uniformly black, as it ought to be. The same well bred bulls were put to the two divisions, and changed from one to the other from time to time. The field in which division A. grazed was located so that no cattle of broken colours could be seen by the animals at pasture in it, while the field in which division B. was kept, adjoined two other fields in one of which up till 1890 were pastured black steers and in the other Ayrshire cows displaying great variety of broken colours. The black polled cows of division B. were within smelling distance and within full view of the cattle in the two fields in question (being separated merely by a wire fence) and, in consequence from 2 to 4 "badly marked" calves were born annually. In 1890 both of the fields adjoining/

adjoining division B. were occupied by red-and-white cattle, with the result that 6 pure bred polled Aberdeen Angus calves came badly marked, some being black-and-white and others red. Some of the cows which bore badly marked calves were 3 or 4 months gone in calf before they were brought in contact with cattle of other colours than their own, from which it maybe inferred that the influence of the imagination is not confined to the period of conception. One of the red calves had a black fringe round his muzzle and a black stripe along the back. This red calf developed into a pure black bull, with a reddish fringe round the muzzle and a reddish stripe along the back.

In 1891 the adjoining fields were intentionally stocked with black cattle exclusively and all the calves of 1892 were for the first time for several years of pure polled Angus colour, like the colour of the sires and dams and of the calves of division A., which bred always true to colour. Only one calf had a small patch of white upon it; and this is a common occurrence in the best bred black polled cattle. The fact that the sires of the badly-marked calves of 1891 were the same as the/

the sires of the black calves of 1892 makes the results of the experiment all the more interesting."

#### DISCUSSION.

---

Firstly, let us see if there be any explanation why "broken colours" should occur at all in a pure herd of Aberdeen Angus. From a study of the history of the breed we find that broken coloured cattle appeared in its ancestry and it is some of this ancestral blood which is the cause of calves appearing with other colours than pure black. How this occurs is easily demonstrated and the explanation is identical with that which Wood (64) has used to explain the occasional occurrence of horns in this same breed of cattle.

Are Aberdeen Angus cattle really pure? The real test of purity is the production of pure offspring. When a black polled bull is mated with a coloured cow the calf is almost invariably black, that is, black colour is dominant to others. Now this calf, the result of above mentioned cross though really a hybrid, looks a pure black polled Angus, and if it be subsequently mated with a pure black Angus the progeny will all be black;- half of them are/

are pure and the other half crossbred or impure though they have all the appearance of pure animals -

$$D(R) \times D(R) = 2D \text{ and } 2 D(R) \\ \text{Black Black.}$$

This may go on for several generations, until an impure dominant meets an impure dominant when one calf in every four produced from such a mating will have a colour other than black, depending on whatever colour has been lying recessive in the impure hybrid. This is what is commonly called reversion, but it really depends on the fact that a black animal may be in reality a mongrel as regards colour and transmit its hidden mongrel nature to its progeny for any number of generations until a mating takes place between two so-to-speak, hidden mongrels when a "broken coloured" calf may appear.

A similar explanation it will be remembered was used to explain the occasional appearance of a black lamb in a white flock.

To return to the experiment in maternal impressions, we at once see how "broken coloured" calves could result. But does this explain all the facts of the case? Attention must be drawn to the fact that some of the cows were from 3 to 4 months gone in calf before they had any opportunity of receiving/

receiving an impression and although it is possible that the maternal imagination might act at such a late date, it seems extremely unlikely that it would. Then again 20% of the calves are spoken of, in one place, as being badly marked. Actual numbers would have been much more satisfactory. In a herd of say 20, one represents 5%, two 10%, and so on. Ten per cent seems a good deal higher than 5% and yet in this case it is only represented by one animal. Yet how can we explain the results of 1892 when all the calves were black? Was it merely a coincidence - a most unsatisfactory explanation? Unfortunately all the cows that produced "badly marked" calves were not tested by further breeding as to their purity to black colour. This, however, would have meant time and a considerable amount of expense.

What more, then, can we say, but that the appearance of such coloured offspring can be explained by Mendelism and that the cause of their appearing in some cases more often than expected may be due to the influence exerted by the maternal imagination, though this is by no means proved?

## H O R S E S.

---

### KINDS.

There are a variety of kinds of horses in Scotland, but the thoroughbred and the clydesdale are the most common, each of which has a stud book.

Little research has been done in the inheritance of colour in horses and we have only a vague idea how one colour or another descends from parent to offspring. Hurst (65) after investigating the inheritance of coat colour in race horses comes to the conclusion that chestnut colour is a recessive to bay and brown which are dominant characters, while Sturtevant (66) who studied the subject as it applied to the American Harness Horse concludes that "the colour in these horses is controlled by five factors".

1. A factor for chestnut (c) present in all horses studied.
2. A factor for black, epistatic to (c) hypostatic to 3,4, and 5.
3. A factor for bay (b).
4. A factor for roan (r).
5. A factor for gray (g).

"R" and "G" inhibits "B" if it is present, but whether they depend upon it for its presence for their own appearance or not is not clear." Here it would appear as if chestnut were again recessive, with roan and gray dominant to all the others. Do these/

conclusions help us much in studying the colour inheritance in Clydesdales with which we are best acquainted. Unfortunately, the method of colour inheritance in this breed would appear never to have been investigated. The chief colours are black, brown or bay, gray chestnut, and white. By far the largest number are brown in colour over the body, usually with a white mark on the face; the hair on the legs is either black or white. Whites, chestnuts, and grays are comparatively rare and being undesirable colours their appearance in the stud-book is more seldom even than one would expect. Have these colours, like the colours of the other kinds of horses already investigated, any Mendelian relationship?

I am indebted to James Watson, B.Sc. for the records of an investigation, not yet published, which he has made into this subject. He says, "The black colour is recessive to all others (Gray, chestnut and all shades of bay or brown). The fact that "blackness" is recessive seems to be proved by three circumstances:--

1. A black stallion and a black mare always produce a black foal.
2. There are abundant cases of two bay or brown parents having a black foal. These animals/

animals according to my theory would be bay black heterozygotes and the chance of a black foal would be one in four.

3. If a sufficient number of the offspring are registered it is quite easy to separate bay or brown stallions into two distinct classes.
  - (a) Those which produce no black foals. To this class belong Darnley and Macgregor these are homozygous.
  - (b) Those which produce quite a large percentage of black foals. This is probably about 10% or 12% but is liable to very considerable variation. These are brown-black heterozygotes among which appear the stallions - "Prince of Wales", "Baron's Pride", "Sir Everard" and "Baron o' Dee".

He arranges the colours in order of dominance:-

1. Gray.
2. Bay-brown.
3. Chestnut.
4. Black.

From a study of this record we see at once the explanation of two brown coloured parents having a black coloured offspring. I came across a very interesting case lately dealing with this very point and as it is closely connected with the subject of maternal impressions I shall give it in detail.

The colour of the famous stallion "Sam Black" (14,348), (his registered number in Clydesdale Stud-Book), I was told, on what I took to be good authority was due to the result of a maternal impression. His mother had had a black horse in view, while she was/

was being served, with the result that her foal was of a black colour. On looking up "Sam Black's" pedigree which being of extreme interest I append, I found that it was not till I had traced his ancestors back six generations that a black horse or mare appeared. Then I found that he had five black ancestors, two of them occurring twice and on tracing his pedigree still further back, it will be seen that quite a large number of black horses appear, often the same horse occurring again and again in different branches of the ancestral tree. Here then we have sufficient explanation of the colour of "Sam Black" - His Sire, "Baron o' Dee" is known to have produced black foals previously and is therefore a brown-black heterozygote. His dam, Alexandrina is of a brown colour and though not definitely known is also in all probability a brown-black heterozygote. The chances, on these two being mated, of their throwing a black foal was one in four and so "Sam Black's" colour is explained. He was the "one".

But the interest in the case does not stop here, what I have to add, I am afraid, is somewhat typical of the evidence brought forward to support the theory of maternal impressions. On writing/

writing the owner of the horse asking for particulars of how the maternal impression took place, I was informed that "the story I had heard regarding the colour of "Sam Black" was totaly without foundation. The owner of "Sam Black" did not have a black horse in his possession. So falls to the ground another well known case of the influence of the maternal imagination.

Harvey (61) and Wallace (63) relate instances of maternal impressions influencing the inheritance of colour in horses and many hearsay stories could be mentioned but what advantage would be gained by their perusal?

The following experiment may be recorded  
 On 24th June 1909 - Sally, a brown mare with three white legs and white face was served today by Aitkenbrae (13.955) a bay coloured stallion with white face and legs. Immediately after service the mare was taken and put beside a black gelding with which she remained in company for two months.

RESULT 2nd June 1910.

Above mare had a brown coloured foal, very similar in appearance to herself. A single experiment, however, is of little avail. Yet we have seen from a study of the preceeding pages/

pages how a Mendelian explanation, similar to that given in the case of sheep and cattle is sufficient to account for most of those cases which up till now have been explained by the maternal impression theory.

Male/

MARE			
The Tifter (br)	Highland Jean (br)		
Rosa		Miss Riddell (br)	
Prince of Wales (br)	Blane (br)		Bella of Balgreddan (br)
Kate	Flora Macivor		
Disraeli (br)		Euxom Lad (br)	
Peggy		Young Fanny	Brisk (br)
Conqueror (br)	Darnley (br)		
Jean			
Conqueror (br)	Fanny		
Mare			
Farmer (br)	Young Farmer (br)	of Boghouse	Flashwood's Best (br)
Jean			
Prince Charlie Sally (White)		Flashwood (br)	
Peggy			
Conqueror (br)	Darnley (br)		
Mare			
Clydesdale	Tom Mall	Forrest Mallie (br)	
Maggie			
Young Campsie B. Pretender			Forrest Queen (br)
Maggie			
Lorne	Skerlim (br)		
			Baron o'Dee (br.)



FEMALE SIDE OF PEDIGREE OF SAM BLACK.

Mare			
Horse	Mare		
Mare		Mare	
Prince of Wales Stanley (br)			
Mare (br)			
Mare (br)			Maggie Taylor (br)
Young Lord Lyon	Jemima		
(br)			
Darling		St. Lawrence (br)	
General (br)	Prince of Wales (br)		Lady Margaret (br)
Mare			
General Williams	A Eute Mare		
(br)			
Mare		Mare (br)	
Prince of Wales (br)	London Prince		
(br)			
Mare <u>black B.</u>	Bell (ch)		Sir Everard (br)
Campsie B.			
<u>Peggy</u>	Darnley (br)	Top Gallant (br)	
Conqueror (br)			
Mare	Maggie		Alexandrina (br)
Clyde (br)			
mare	Lord Lyon (br)	Sally (br)	
Hercules (br)			

Mare	Peggy	Jeanie Black (br)
Logan's Twin (br) Mare	Darnley (br)	Prince Alexander (br)
Loch Fergus(br)Conqueror (br) Champion		
Mare		
Horse		
Mare	Logan's Twin(br)	Prince of Wales (br)
Lofty	Darling	
Mare		
Horse		
Mare	Sir Walter Scott (Br)	General (br)
Old Clyde (br)		
		ALEXANDRINA X BARON O' DEE
		SAM BLACK.

On tracing the pedigree of "Sam Black" still further back, the following seven black horses are met with:-

1. Thompsons Black Horse (335) foaled about 1810.
2. Allens Black Horse (1571).
3. Campsie (119).
4. Young Campsie (929).
5. Angus McGeachy's Black Horse, grand sire of Skerlim.
6. A black mare grandmother of "Top Gallant" and (7) a black mare great grandmother of Blane.

Of course owing to the lack of sufficient registration of females, there may have been other blacks in his ancestry, but we can at least trace him to these seven and it is interesting to note that these seven horses appear over fifty times in his pedigree.

## R A B B I T S.

### COLOUR OF RABBITS

Thanks to the researches chiefly of "Hurst" (67) and "Castle" (68) in regard to colour inheritance in rabbits we have now a clear conception of what actually takes place in crossing animals of different colours. Castle recognises several different unit/

unit characters as necessary for the production of all the different colours. The chief of these unit characters, and those with which we are mainly concerned are,

- (c) A factor for the production of colour and without which no colour can be produced.
- (b) A factor for black.
- (Y) A factor for yellow..
- (a) A factor for a barred arrangement of the pigment in the hair which along with B. Y. and C. gives rise to the gray rabbit.

There are other factors, for example, factors for "selfcolour", "dutch markings", "intensity" and "diluteness" of pigmentation, but we may for the present leave these out of account.

A gray rabbit may be represented as carrying the factors "C" "B" "Y" "A", a black "C" "B" "Y" while an albino, lacking as it does the factor for colour production (c) is represented either as "B" "Y" "A" or "B" "Y" according to whether it carries gray or black as a latent colour, which only require the presence of (c) for its manifestation. These points have been abundantly demonstrated by "Hurst and Castle" the latter concluding by saying "All that an albino seems to lack in comparison with a pigmented animal is an activating substance and even this may be present in small amounts in the albino as for example in the Himalayan rabbit and in the similar variety of the

albino/

albino guineapig. Whether an albino carries black or gray as a latent colour, can only be demonstrated on crossing the albino animals with an animal which contains the factor (c). Albino crossed with albino always breeds true to colour no matter what be the latent colour. Gray of course is dominant to black as it contains an extra factor (a).

#### CHOICE OF MATERIAL.

We have now sufficient knowledge to proceed to arrange experiments in maternal impressions. What colours are we to select? Black I may say is inadmissible, owing to the great difficulty of procuring black rabbits that breed true to blackness. "Woods" (70) having shown that out of 150 offspring, where both parents were black, 105 were black, 28 albino, 9 gray and 8 yellow. We must start with animals the result of whose crossing we can depend upon. It was decided to conduct experiments as follows:-

1. To cross albinos, shown to contain latent black (B.Y) and see if a maternal impression could cause the manifestation of the black colour in the offspring.
2. To cross Himalayan albinos, (that is albinos carrying a small amount of the activating substance (c)) which were also shown to contain latent black and see if a maternal impression could not cause the black colour to appear in the young.
3. To/

3. To cross two grays (C.B.Y.A.) which were known to breed true and see (1) if a maternal impression could cause the factor (A) to fall out and so cause the colour of offspring to be black (CBY) or (2) if a maternal impression could not cause the factor (c) to fall out and so cause the colour of the offspring to be white (B.Y.A.)

These experiments, I think, should give the maternal imagination every chance to demonstrate its power.

In all these cases it has to cause either the appearance or disappearance of a factor. It has something definite to do.

We may now relate the experiments and their results

#### EXPERIMENTS WITH RABBITS IN MATERNAL IMPRESSIONS

EXPERIMENT NO. I. - with a pure albino doe No. I.

DATE	SIRE	COMPANION DURING PREGNANCY	RESULT
28.12.08.	wild gray	albino	5 gray
8.3.09	albino (20)	albino	8 albino
22.5.09	albino(20)	for 1st day albino covered with black silk cloth.	9 albino
5.7.09	albino(20)	black doe all the time.	3 albino
1.2.10	albino(20)	2 gray does all the time	7 albino

NOTE. Doe was extremely cross when buck was put beside her, covered with black silk and they fought together for a considerable time. Black covering taken/

taken off after first day. On other two occasions first when black doe was put along with her, and then in the next pregnancy when the two gray does were added, there was a good deal of fighting for the first day or two. The first cross with the wild gray is to enable us, as will be shown later to demonstrate that this albino doe was carrying latent black.

EXPERIMENT NO.II. - with pure albino doe No.II.

DATE	SIRE	COMPANION DURING PREGNANCY	RESULT
5. 2.10	albino(20)	black doe all the time	6 albino
11. 4.10	albino(20)	black doe for 1st three days	6 albino
19. 5.10	Belgian Hare	albino	5 gray - more the wild rabbit gray than the yellowish gr. of the Bel. Hare

NOTE. This doe was afraid of black doe and underwent a considerable amount of hardship during the first few days they were together, a lot of her hair being torn out in the fighting.

EXPERIMENT/

## EXPERIMENT NO.III. - with Himalayan doe NO.III.

DATE	SIRE	COMPANION DURING PREGNANCY.	RESULT
19.10.09	Himalayan	Himalayan	3 Himyn.albns.
13.12.09	Himalayan	pure black flemish doe fr.beginning till 12.12.09	6 " "
15. 4.10	Himalayan	black flemish doe till 9.4.10	5 " "
30.7.10	Belgian Hare		7 very dark gr. one nearly completely black.

NOTE. Considerable amount of fighting, as in the other cases mentioned, when the black does were added. It is scarcely necessary to add that during the whole pregnancy, the does were completely shut off from seeing any other rabbits than those mentioned. This applies to all the experiments.

## EXPERIMENT NO.IV. - with Himalayan Doe No.IV.

DATE	SIRE	COMPANION DURING PREGNANCY	RESULT
20.2.10	Himalayan	2 black flemish does during whole time	5 Himalayan albinos
2.6.10	Himalayan	black doe - all the time	3 " "

EXPERIMENT/

## EXPERIMENT NO.V. - with Belgian Hare No.V.

DATE	SIRE	COMPANION DURING PREGNANCY.	RESULT
24,12,09	Belgian Hare	Belgian	2 Belgian
20.3.10	Belgian	Himalayan doe	3 Belgian.

## EXPERIMENT NO.VI. - with Belgian Hare No.VI.

DATE	SIRE	COMPANION DURING PREGNANCY	RESULT
17.4.10	Belgian	Belgian	8 Belgian
22.6.10	Belgian	Black doe all the time	8 Belgian

NOTE. The method in which the black does were added to the hutch in which was the doe being experimented on was as follows. The male and female animals were first mated together and then suddenly the black doe was dropped in beside them, often to their great astonishment and usually they were not slow to resent the intrusion of the black.

Unfortunately disease began to spread amongst my Belgian hares, hence the paucity of results.

I shall now relate experiments to show the presence/

presence of latent black in the albinos and Himalayan does. These already, it will be seen, have been mated with grey coloured animals so we have only to record the result of intercrossing the progeny resulting from these matings.

EXPERIMENT NO.VII.- Intercrossing gray rabbits, the progeny of albino No.I and a wild gray male, born 28.12.08.

DATE	NO. of DOE	MALE	RESULT.
3.6.09	No.7	No.10	4 gray & 1 black
5.6.09	No.8	No.10	3 albino, 1 black & 1 grey with white face & white ring round neck.

EXPERIMENT NO.VIII. - Intercrossing gray rabbits, the progeny of albino No.2 and a Belgian Hare, born 19.5.10.

DATE	No. of DOE	MALE	RESULT
3.2.11	No.12	No.11	3 gray & 1 black
4.3.11	No.13	No.11	2 white & 2 gray.

EXPERIMENT NO.IX. - Intercrossing dark gray rabbits, the progeny of Himalayan doe No.III, and a Belgian Hare, born 30.7.10.

DATE	NO. of DOE	MALE	RESULT
14.3.11	No.14	No.15	2 grey, 1 white & 1 blk. all died young before any himalayan characters appeared in the white.

From a study of these results it will be seen that each of the does mentioned must have carried latent black. It was impossible for the black to have been brought in by the males as they are all known from a study of their previous records to be pure grays. They, the males, contain the colour factor (c) and if they were not pure to grey, black would very soon make its appearance, whereas in the case of the albinos, as mentioned before, it is the lack of this factor (c) that prevents the factor for black from finding expression. The colour factor (c) is brought into the cross by the gray, and hence it is that we find black appearing in the second filial generation.

#### DISCUSSION of RESULTS.

---

No support of the maternal impression theory can be deduced from the results of the preceding experiments. In not a single case is there any evidence that the maternal imagination has any influence whatever. Whether rabbits be impressionable animals or not, does not seem to be known, but otherwise, owing to the fairly exact knowledge we have in regard to their inheritance of colour, they seem admirably fitted for the conducting of experiments in maternal impressions.

CONCLUSION/

## C O N C L U S I O N .

---

A Maternal Impression rarely if ever interferes with the normal inheritance of colour in animals. So much is recognised from an impartial survey of the experiments and cases recorded. We may safely affirm I think that it is powerless to cause the appearance in the offspring, of a colour, the factors for which are absent from both parents. We have seen this, not only in the case of white-faced sheep, but more markedly in the case of rabbits, where, for example in himalayans it is even unable to cause an increase in the amount of a factor (c) which is present, though in small amount. Equally is it powerless to cause the disappearance of a factor as seen from the experiments with Belgian hares.

In a review, however, of the crosses between white-faced and black-faced sheep and also of certain crosses with cattle, we recognise results not in accordance with expectation, and the possibility has to be recognised that maternal impressions may have an influence in these cases, though it is by no means definitely proved that such is the case. Where two colours are expected to appear in a certain proportion/

proportion to each other the maternal imagination may intervene and upset this proportion, that is, it is only in those cases where all the factors are present for the manifestation of both colours, that this influence may come into play. We have seen above that it cannot cause a factor to appear or disappear, hence the only way it can act is either by influencing the output of the different colour-bearing gametes, or when two different colour-bearing gametes meet to form a zygote by influencing the power one unit character has of becoming dominant over the other and so determining the colour of the offspring.

Even if a maternal impression have this power, we are led to a new conception of the theory. If an impression can only influence the possibilities then it would appear to make little difference what the nature of the impression is, and we need not expect the result of the impression to resemble the exciting cause. Any cause upsetting the internal economy of the animal would be sufficient to produce the variation. So that in any case we have to give up the old theory of maternal impressions, and what is left of the theory is more in harmony with our present day knowledge. As mentioned earlier/

earlier in this thesis, shock and distress can produce prejudicial effects on the unborn, that is, the development of the body does not take place naturally and we get some developmental error. Why, then should we not admit the possibility, till proof one way or the other be forthcoming, that shock distress etc. may produce a prejudicial effect on the normal development and manifestation of the unborn animals colour, and this is all that can now be claimed for the ancient theory of Maternal Impressions.

Before closing, I should just like to mention two suggestions as to the modus operandi which I have come across since starting this thesis. They seem to be in partial agreement with views advanced earlier in this work. They are recorded by Ballantyne (71)

"The first suggestion is obtained from Darest'e (72) well known experiments upon the artificial production of monsters. The observer found that the two conditions which most certainly affected the blood supply of the embryo were those which most effectually influenced its development and these two conditions were:-

- (a) the contact of the ovum with a source of heat at a point near to but not coinciding with the cicatricula.
- (b) the production of temperatures slightly above or below that of normal incubation.

Now these are exactly the conditions which it is possible/

possible to conceive occurring in utero in consequence of the alterations in the blood supply of the uterus and foetus from maternal emotions.

The second suggestion is from Hirst (73) - may not the disastrous effect produced upon the foetus by strong emotion on the part of the mother be explicable in the light of the recent researches into the formation of ptomaines and leucomaines. If the maternal emotion can diminish the supply of oxygen to the foetus may it not also change the composition of the blood?

#### S U M M A R Y .

---

- I. A maternal impression has no influence in colour inheritance to produce a colour de novo.
  - II. A maternal impression may influence the proportion in which certain colours, the result of known crosses, are expected to appear.
  - III. There is no evidence to show that, even if a maternal impression have this power, the resultant colour is necessarily similar to the colour producing the impression.
-

R E F E R E N C E S .

---

1. JACOB. Genesis chap. xxx verse 32 to the end
2. BALLANTYNE (J.W.) Teratogenesis - A History of the theories of the Past (Oliver & Boyd, Edinburgh) 1897.
3. PREUSS (J.) Vom versehen der Schwangeren, ein historischkritische Studie. Berlin Klinik, Hft. 51 pp. 1-50, 1892.
4. DELAGE (YVES) - L'Hérédité et les Grandes Problèmes de la Biologie Générale 2nd Editn. 1903.
5. PROSPER LUCAS - Traité philosophique et physiologique de l'Hérédité naturelle 1847 & 1850 Vol. I & II.
6. EMPEDOCLES - see Plutarch, De placitis philos, lib. V. c. 12, cited by Fienus (T) in his De Viribus imaginationis p. 217 Lugd, Batav. 1635.
7. BLONDEL (J.A.) "The Power of the Mother's Imagination over the Foetus examined" London 1729
8. PREUSS (J.) Vom Versehen der schwangeren p. 49
9. HARVEY (A). Monthly Journal of Medical Science Ed. & Lond. Vol. xi. 1850, p. 396.
10. HARVEY (A). ibid p. 391.
11. HEREDITY by J. Arthur Thomson p. 162
12. CRUIKSHANK - Monthly Journal of Medical Science Vol. xi. 1850,
13. WALLACE (Professor) Farm Live Stock of Great Britain Oliver & Boyd, 1907. pp. 12 & 13.
14. WORTLEY AXE. (Prof.) The Horse - its treatment in health & disease p. 497
15. "THE SCOTTISH FARMER" April 17th & 24th 1909.
16. Dr. Leslie Mackenzie, Scottish Medical & Surgical Journal VI., 1900, p. 362. (Discussion on Heredity in Disease).

17. BALLANTYNE (J.W.) Article on Maternal Impressions in Encyclopaedia & Dictionary of Medicine & Surgery. 10 Vols by Green.
18. FORDYCE BARKER (Dr.) Trans.Amer.Gynec.Soc. 1886, XI.p.152
19. BUSEY (Dr.S.C.) Trans.Amer.Gynec.Soc.1886.XI. p.176.
20. DONCASTER (L.) Heredity p.97 Univ.Press Cambridge (1910)
21. DELAGE (YVES) - L'Hérédité et les Grandes Problèmes de la Biologie Generale 2nd Edit. 1908, p.248.
22. HARVEY (A). Monthly Journal of Medical Science Ed.& Lond. VolXI. 1850.
23. THOMSON (J.ARTHUR) - Heredity 1908 pp.162 & 163.
24. TUKE (Dr.D.H.) - Influence of the mind upon the Body in Health & Disease, designed to elucidate the Action of the Imagination. Vol.II. p.67.
25. QUOTED by J.ARTHUR THOMSON in "Darwinism & Human Life p.122
26. DURHAM (FLORENCE) Note on Melanins - Journ.of Physiol.35, 1906-7 p.47.  
\*  
See also Proc.Roy.Soc.Lond.Vol.74, 1904, p. 310.
27. BERRY HART (Dr.D.) Some phases in Evolution & Heredity. (1910)
28. BATESON (Professor) Principles of Mendelism 1909 pp.192 & 193
29. WEISMANN - The Evolution Theory Vol.III.p.117 1904 (Trans.by J.A.& M.R.Thomson and quoted in Thomson's Heredity).
30. WEISMANN ibid Vol.II.p.156
31. RIDDLE (O.) Our knowledge of melanin-colour formation and its bearing on the Mendelian description of Heredity. Biological Bulletin 16, 1908-9.p.316.

32. HLASIWITZ (H.) & HABERMANN (J). Ueber die  
proteinstoffe Leibig's Annalen 169 p.150.
33. BERTRAND (G) ('96) Sur une nouvelle oxydase  
ou ferment soluble oxydant d'origine vege-  
tale Bull. Soc. Chim. 3d Ser. T. xv. p.791
34. DURHAM (Flor.) - Proc. Roy. Soc. Lond. Vol. 74  
on the presence of Tyrosinase in the skins  
of some pigmented Vertebrates.
35. Von FÜRTH (O) & SCHNEIDER (H) ('01) Ueber  
tierische Tyrosinasen, ihre Beziehungen zur  
Pigmentbildung, Hofmeister's Beitrage Bd. I.
36. DEWITZ ('02) Recherches experimentales sur  
la metamorphose des insectes.  
Compt. rend. T. 54 p. 44
37. GESSARD (M.C.) Sur la formation du pigment  
melanique dans les tumeurs du cheval  
Compt. rend. soc. biol. T. 136 p. 1086
38. PFORRINGER, Zur entstehung des haut pigments  
bei morbus Addison, Cent. f. Allg. Path. (11)
39. TORNIER (GUSTAV) Nachweis ueber das Entstehen  
von albinismus, melanismus and neotemie  
bei Fröschen - zool. Anz. Bd. 32, p. 284.
40. SPIEGLER - Hofmeister's Beitr. z. Chem. Phys. V.  
Path. 4. 40, 1904.
41. GORTNER (Dr ROSS AIKEN) American Naturalist  
Augt. 1910.
42. CHANTEMESSE & PODWYSSOSKI. Path. Vol. I. p. 281.
43. DAVENPORT (G.C. & C.B.) American Naturalist  
Novr. 1910. p. 642.  
Heredity of Skin Pigmentation in Man.
44. GATES (Dr. REGINALD R.) American Naturalist  
April 1910.  
("The Material Basis of Mendelian Phenomena")
45. MORGAN (T.H.) Journ. Exptl. zool. 7: 239-352,  
1909.
46. DELAGE (YVES) L'Hérédité et les grandes Pro-  
blèmes de la Biologie Générale. Paris  
2nd Edn. 1903 p. 749.
47. DELAGE (YVES) ibid p. 796.
48. DELAGE (YVES) ibid pp. 832 & 833.

49. WILSON (E.B.) The cell in relation to Heredity & Evolution in Fifty Years of Darwinism p.110.
50. RUSSO (A). Studien über die Bestimmung des weiblichen Geschlechtes" Fischer Jena 1909.
51. PUNNETT (R.C.) Proc.Camb.Phil.Soc. Vol.15 Pt.2.p.92 1909.
52. MacDougal (Prof.D.T.) The direct influence of the Environment. Fifty years of Darwinism 1909.
53. PROFESSOR TOWER - Fifty Years of Darwinism p.125.
54. THOMSON (J.ARTHUR) Darwinism & Human Life.
55. THOMSON(J.ARTHUR ) Heredity 1908, p.161.
56. TRANS. Amer.Gynec.Soc.1886 XI. p.176
57. DAVENPORT (C.B.) Science XXII.1905 p.674 -675
58. CASTLE (W.E.) Papers of Station for Experimental Evolution at Cold Spring Harbour, New York. No.2.
59. BARRINGTON A. & PEARSON (K.) Biometrika Vol.IV. p.427 on the Inheritance of Coat Colour in Cattle.
60. WILSON (JAMES) Nature April 2, 1908, p.509 "Mendelian characters among shorthorns."
61. HARVEY A. Monthly Journal of Medical Science Ed.& Lond. Vol.XI. 1850.
62. THOMSON (J.A.) Heredity 1908, p.380.
63. WALLACE (Professor) Farm Live Stock of Great Britain pp.13 & 14.
64. WOOD (T.B.) Heredity in Farm Animals "Scottish Farmer" 29.1.10.p.95.
65. HURST (C.C.) Proc.Roy.Soc. 4 XXVII, 1906, p. 388. "On the Inheritance of coat Colour in Horses".
66. STURTEVANT (A.H.) Biological Bulletin Augt. 1910. p.254. "On the Inheritance of Colour in American Harness Horse".

67. HURST (C.C.) The Journ.Linnean Soc.(zool.)  
Vol.xxix 283-324- Experimental Study on Here-  
dity in Rabbits.
  68. CASTLE (W.E.) Studies of Inheritance in  
Rabbits Carnegie Institute Washington 1909.
  68. CASTLE (W.E.) Carnegie Inst.Washington No.23  
1905. Heredity of Coat Characters in  
Guinea Pigs & Rabbits.
  69. CASTLE(W.E.) Science (26) 1907 p.287.  
Colour Varieties of the Rabbit &c.
  70. WOODS (.F.A.) Biometrika Vol.II.p.299 "Mendel's  
Laws and some Records in Rabbit Breeding.
  71. BALLANTYNE (J.W.) Edin.Med.Journ.36 Pt.ii.  
1891 p.624. Maternal Impressions.
  72. DARESTE - Comptes Rendus 1873.
  73. HIRST - Keatings Cyclopaedia vol.I. p.213.  
Article on Diseases of Foetus.
-