

Thesis for M. D.

SOME PROBLEMS IN VARIATION AND HEREDITY.

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In the "Conclusion" to the Origin of Species Darwin sums up his views in these words: "I have now recapitulated the facts and considerations which have thoroughly convinced me that species have been modified during a long course of descent. This has been effected chiefly through the natural selection of numerous successive, slight, favourable variations; aided in an important manner by the inherited effects of use and disuse of parts; and in an unimportant manner that is in relation to adaptive structures, whether past or present, by the direct action of external conditions, and by variations which seem to us in our ignorance to arise spontaneously".

The fact of organic evolution is no longer disputed; the many different lines of evidence so ably marshalled by Darwin in his great work were sufficient in themselves to bring most biologists to share his view that "species have been modified, during a long course of descent"; and since his day further proofs have accumulated. A general agreement on this matter now prevails. But no such unanimity yet exists concerning the means by which such modifications have been effected. During the past twenty-five years a great controversy has been carried on regarding the factors which may have been concerned in the process of development and no certain conclusions have yet been reached.



Darwin explained and exemplified very fully and convincingly the working of his principle of "the natural selection of numerous successive, slight, favourable variations"; and he considered this to be the chief factor. But he allowed, at the same time, that the Lamarckian factors had an important, though a somewhat subordinate part to play in the origin of species. After his time a school of biologists, consisting of Weismann and his followers, has arisen which rejects the Lamarckian factors in toto and maintains that natural selection acting upon fortuitous variations, is sufficient in itself to explain organic evolution. Another school, to which Herbert Spencer and Haeckel belong and which finds a large support in America especially amongst the paleontologists, while admitting that natural selection has played an important part in evolution, emphasises the relative importance of the environmental and functional changes produced in organisms and lays stress on the transmission of acquired character. Some even go so far as to throw the whole burden of evolution on the Lamarckian factors.

A third school, represented by Nageli, Henslow, Eimie<sup>r</sup> and others, rejects the view that variations are haphazard, believing on the contrary that they occur in a determinate direction due to some force which is thought to be at work within the organism and prior to the operation of natural selection. The nature of this force is not very clear and the different writers probably do not always mean the same thing: it has been variously called

"growth-force", "bathmism", "self-adaptation", etc. Some of the terms employed have a teleological <sup>aspect</sup> ~~view~~ about them. They recall to our minds those expressions concerning an "inherent tendency towards progression" which are found in the writings of the older naturalists and philosophers as far back even as Aristotle. The writers belonging to this school are evidently striving to give utterance to some ideas which they have in their minds but which they have not yet succeeded in putting in clear and unambiguous terms; the expressions used are but approximations <sup>to the ends which</sup> ~~to words which~~ they want to convey. They seem to be groping after some as yet undiscovered law or laws of growth and development.

From all this it is evident that the problem of the origin of species is as yet far from being solved. Biologists are now busily engaged in pushing their enquiries further back than was done by Darwin. Variations must be present for natural selection to work upon, so there is something to explain before natural selection can begin its work. This was admitted by Darwin himself: in his Animals and Plants under Domestication (2nd.Ed. Vol.I., p.277) he says "Natural Selection has no relation whatever to the primary cause of any modification of structure". He took the variations which are found to occur in nature as his starting-point. Regarding the causes of variation he tells us repeatedly that he is profoundly ignorant, and nowhere in his works do we find any attempt to explain them.

Again, touching the question of Heredity, Darwin concluded, on what is now generally regarded as insufficient evidence, that acquired characters are transmissible; and in order to show how this might be possible he promulgated what he termed a "provisional hypothesis of Pangenesis". But it is now recognised that the problems of Heredity still remain unsolved and that its laws have yet to be discovered. The transmissibility of acquired characters has been called in question and is totally denied by a great number of leading biologists at the present day.

Darwin took Variation and Heredity as his basis and upon these two pillars he built up his theory of the origin of species and the evolution of organic forms. Biologists are now pushing their enquiries further back; they are not content to take Variation and Heredity as facts which require no further explanation. It is now realised that the causes of Variation must be understood and the laws of Heredity discovered before the problem of development can be fully solved. It is by the observation of what takes place at the earth's surface to-day, or what has taken place recently, that geologists have found the clue by means of which they can unravel the origin and history of the rocks which make up the crust. The present is always found to be the key to the past. It is only by employing a similar method that biologists can hope to attack successfully the problems of Variation and Heredity. By actual observation and experiment they must seek to determine how species are being

modified around us to-day and find out what characters are transmissible. The nature and causes of Variation and of Heredity will thus in time come to be understood.

It is only within recent years that any attempt has been made to study variations systematically. Mr. Bateson's work, entitled Materials for the Study of Variation, is an important contribution in this direction. He is not content with the knowledge that variability exists but seeks to find out by detailed investigations of particular cases what variations actually do occur in nature. He brings forward evidence to show that there are variations which cannot be arranged in a continuous series - that such variations are therefore discontinuous. This is not peculiar to any one kind of variation. This discontinuity of variation is something akin with polymorphism - in fact it may be regarded as one of the forms under which polymorphism may show itself. Darwin never contemplated the existence of polymorphism, except where the polymorphism is of some advantage. But the test of utility cannot be applied to explain the definiteness of structure which is so often seen. Differences appear often in the most trivial points. Darwin never entertained the idea that discontinuity could be a starting-point of species. He tended to regard variation as always slow and almost imperceptible: species arose by the natural selection of "numerous successive, slight favourable variations".

If variation is frequently discontinuous and large in amount, as the evidence seems to show, it is possible, as was long ago suggested by Geoffroy St. Hilaire, that there may have been leaps and bounds in Evolution. Mr. Bateson suggests that in these discontinuous variations we may often find the variations out of which new species arise. In that case natural selection is not such an important factor in the origin of species as the Darwinians have supposed. Other naturalists, notably De Vries, have within recent years recognised the existence of discontinuous variations. Bateson confined himself for most part to the study of variations in the number, symmetry, and arrangement of parts; to these variations he applies the term <sup>meristic</sup> miraclic. The discontinuity between variations is seen in the repetition of parts and in the phenomenon of symmetry. Sudden and complete changes in colour are also often seen and numerous examples among plants are given by De Vries. Mr. Bateson also points out that there is a greater definiteness of variation than has been generally recognised by Darwinians. This raises one of the most important problems which has to be solved concerning the nature of variations, namely, the question of whether variations are always haphazard or whether they occur in definite directions. During the last few years many biologists have come to the conclusion that variations are determinate. The study of fossils has led the American paleontologist to adopt this view. And it

is to account for this determinate variation that the theory relating to some force at work prior to selection - variously called "growth-force", "self-adaptation", etc., - has been propounded.

Galton was the first to apply the statistical method to the study of variations and his work has been further carried on by Karl Pearson, Weldon, and others. Some measurable character is taken - as stature in man - and the common or average height is noted, for instance in the recruits for the Army. The departures from the normal in the two opposite directions are counted and the results represented graphically. In a great many cases the departures from the middle form or mode are even or symmetrical. This is the case with stature. As the variations become great they are seen to be rarer. In fact the variations about the mode correspond with the laws of chance. The variability can thus be displayed graphically by a curve and a mathematical expression can be found to represent this curve. So it is possible to arrive at the measure of variability displayed by the organism. The variability is greater the flatter the curve is. Cases dealt with in this way are especially numerical cases, such as the number of stamens and carpels, the ratio of length to breadth, etc. Cases are found, however, where the curve is not symmetrical - for instance, the strength of sugar in beet-root. Whenever the curve is asymmetrical there must be something other than mere chance at work. Cases occur also in which variations



are seen only in one direction as is exemplified in the <sup>bell</sup>~~cup~~ where the number of petals may constantly exceed five (the normal number), but hardly ever, if ever, falls below five.

In some instances the members with a particular kind of variation are found to run to two common forms and those commonest forms are not the mean (arithmetical) form.

The great drawback in the application of the statistical method is that there is often no <sup>exclusion</sup>~~exclusion~~ by which we can distinguish between variations which are congenital and variations which are acquired, <sup>and</sup> so no light is thrown on the problem of the origin of the innate characters of species.

Regarding the causes of variation biologists still profess great ignorance. But the experimental work which has been carried on during the past years has shed some new light on the problem. Professor <sup>S</sup>Consar Ewart is one of the foremost workers in this field and some of the results of his observations and experiments are given in a work entitled The Penycuik Experiments and a general summary is given in his address before the British Association at Glasgow (1801) on "The Experimental Study of Variation". From his experiments <sup>in</sup> ~~of~~ the breeding of pigeons and of rabbits he concluded that age is a possible cause of Variation. It is possible also that the offspring may vary with the condition of the germ-cells at the moment of conjugation. For instance, Mr. H. M. Vernon,

in his experiments on echinoderms, found that "the characteristics of the hybrid offspring depend directly on the relative degrees of maturity of the sexual products". Professor Ewart's experiments on rabbits pointed to a similar conclusion. The condition of the soma and changes in Habitat <sup>also</sup> ~~has~~ <sup>we</sup> been usually supposed to cause variations but it is questionable whether these become impressed on the germ-cells in such a way as to be transmissible to the next generation.

With regard to ~~sub~~ <sup>inter</sup>-crossing and inter-breeding Professor Ewart's conclusion was "that ~~sub~~ <sup>inter</sup>-crossing, though a direct cause of retro-gressive variation, is only an in-direct cause of progressive variation, while inter-breeding (in-and-in breeding) at the right moment is a cause of progressive variations". And after discussing the swamping effects of inter-crossing he claims to have shown "(1) that progress in a single direction is probably often due to new varieties swamping old, it may be long established varieties; and (2) that sexual varieties may be sufficiently exclusive to flourish side by side in the same area, and eventually (partly owing to their aloofness, i.e., to differential mating) give rise to ~~sexual~~ <sup>several</sup> new species".

The vexed question as to the inheritance of acquired characters is still undecided. Weismann's theories of Heredity and of Organic Evolution have forced biologists to distinguish at least theoretically between those characters which are congenital or inborn and those characters which are acquired by each individual in consequence of its own peculiar experience. Acquired characters are those that are impressed on the organism by the direct action of the environment, or which arise as a result of the use and disuse of parts. The old view was that the difference in question was merely one of degree, and not one of kind. The differences in degree related to the fullness and certainty with which the character was inherited. But acquired characters might in time, if continuously developed in each individual through many succeeding generations, become congenital. There was thus no essential difference between them. But this is just the point which Weismann has challenged. According to his theory of Heredity there is a great difference between acquired and congenital characters. The one can never pass into the other. It was in 1883 that Weismann first gave to the world his theory of the Continuity of Germ Plasm. This germ-plasm is taken to be the material basis of heredity and is handed down from generation to generation. Changes produced

in the body are not transmitted for this germ-plasm occupies a sphere of its own and is uninfluenced by any environmental and functional changes which may appear in the soma. The soma merely serves for the lodgement and nutrition of the germ-plasm. Thus the relation of each individual to the inherited characters is merely that of a trustee. It hands on to the next generation what he received from the previous one and this germinatal material is totally unaffected by any habits which he may have formed or any changes which his body may have undergone due to the action of external circumstances.

Weismann's theory of the continuity of the germ-plasm has been accepted by many on account of its simplicity. But this in itself is no justification for the acceptance of any theory. The theory must be tested by observation and experiment. As regards variation, he admits that in the case of unicellular organisms changes have been brought about by the environment. In fact so far as the Protozoa are concerned he is a strict Lamarckian. But all variations among the Meta-zoa are ascribed to different sources. He traces them to the commingling of the qualities of the germ-plasm of the two parents which occur in fertilisation. To him this is the chief function of <sup>sexual</sup> ~~racial~~ propagation and he speaks of it as amphimixis. He has also referred to another possible source of variation - the reducing division which takes place prior to fertilization in the <sup>unlike</sup> ~~materialism~~ of the ovum, or in the course of spermatogenesis.

Again he has been forced by the accumulation of evidence from many quarters to modify somewhat his views concerning the influence of environmental changes on the germ-plasm. He admits that the germ-plasm may be affected directly by change in environment, and ~~like~~ <sup>later</sup> he has even allowed that changes of climate and nutrition may act through the body on the germ, not to produce ~~sexual~~ <sup>similar</sup> changes in the next generation, but as stimuli causing some amount of variation.

While Weismann's theory of heredity shuts out altogether any possibility of the Lamarckian factors having played a part in the origin of species among the Metazoa, a theory had been formulated by Galton some years previously (1870) which was also based on the idea of the continuity of the material basis of heredity but which did not exclude the possibility of the substance being modified to some extent occasionally by the somatic tissues. And as pointed out by Romanes (Darwin and after Darwin, Vol II.p.47) the Lamarckian factors even if admitted to a slight degree must have had an enormous influence in determining the course of organic evolution; "seeing that their action in any degree must always have been directive of variation on the one hand, and cumulative on the other.

It is now recognised that the problems of Heredity and that of the transmissibility of acquired characters are not to be settled by hypothetical speculations. The appeal must be made to facts - the accumulation of observations and the

performance of proper experiments will alone lead to their solution. A new school of experimental evolutionists has arisen whose avowed object is to eschew speculation and to find out what actually does occur in nature. It is important to find what part acquired characters play in the origin of species. Acquired characters form a large proportion of the characters of adults. How large it is not easy to determine. It is often too readily concluded that characters which appear constantly in successive generations are congenital; many of them are doubtless acquired afresh by each generation owing to the fact that the external conditions remain constant. It has not yet become possible to separate with certainty those characters which are genetic from those which are acquired. Though much has been done already, more experimental evidence is still needed with a view of finding what characters depend upon the environment. Plants and animals require to be placed under new conditions and the results noted. And with rapidly breeding forms the observations can be continued for many generations. In carrying out such experiments it is of great importance to note not only the changes which occur in the organism when brought under new conditions but also, and this is too often forgotten, to find what happens to such organisms when transported back to the old conditions. This would throw light on the question of the transmissibility of acquired character. Botanists, as a result of these <sup>ex</sup>periments and observations are fairly unanimous

in the belief that by altering the conditions of temperature, light, moisture and especially nutrition, under which the plant is growing, many of its characters will become modified permanently. De Vries, for instance, in the account which he gives of his cultivation of monstrosities shows this to be the case. (\*) Taking the poppy as an instance he shows it entirely depends upon the manuring, upon the distance left between the seedlings, upon the temperature and light supplied, etc., - whether he obtains from the seeds of the many-headed variety of poppy similar forms or individuals which will only have the rudiments of the additional heads. He points out that ~~other~~<sup>these</sup> influences must be brought to bear on the plant in early youth, otherwise the results are not shown. The keeping up of the new variety, also, depends upon its nutrition. Botanists also lean to the belief that these acquired characters are transmitted by inheritance.

Among animals the evidence is not so clear. But many interesting observations have been recorded. A seasonal dimorphism is often seen in moths and butterflies. Experiments conducted by ~~Mason~~<sup>anti</sup>field, Weismann, Standf~~ord~~<sup>ord</sup>, and others, have proved that "one of the two ~~sexual~~<sup>seasonal</sup> forms may be bred from larvae of the other form by simply altering the temperature under which the larvae are reared".

Poulton in his book on Colour in Animals gives an account of the changes of colour in butterflies caused by the differences

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(\*) Kropotkin, see Nineteenth Century. Sep. 1901.

of conditions of temperature and light under which the caterpillars and pupae are reared. Again changes are often seen in the colour of birds, caused by feeding them on different foods. J.T. Cunningham in the Journal of the Marine Biol. Assoc. 1893 has shown the changes in colour produced in flat fish when exposed to the light. An account of H.W. Vernon's work on Echinoderms is given in Science Progress 1897. The sizes of the larvae and the proportion of their different parts may be altered by mere changes of temperature. Changes are also produced by altering the salinity of the water or the proportion of nourishing substances contained in it. *Development*, 1894. It has been

Again there is the well-known case of Artemia salina, where we have one species of this phyllopod crustacean changed into another, by altering the amount of salt in the water.

Thus a mass of evidence is growing which shows how variations in the structures and the forms of animals and especially of plants may arise as a result of environmental changes.

Now many of the characters which are thus changed have hitherto been regarded as specific characters. This at once raises the question of whether or not all specific characters are congenital. If they are all inborn then it must follow that the characters due to environmental changes are transmissible by inheritance. If on the other hand the specific characters in question are not inherited they must be acquired afresh by each generation. On this view acquired characters would play



an important part in the origin of species though a very different part to that which is usually ascribed to them by the Lamarckians.

There is another possible way in which acquired characters might play an important part in organic evolution even though it should be finally proved that such characters are never transmissible by inheritance. This method has been conceived independently by Professor Lloyd Morgan, Professor Mark Baldwin and Professor H.F.Osborn, and had previously been suggested by Weismann himself (Romanes Lecture on "The Effects of External Influences on Development", 1894). It has been called "organic selection" by Baldwin (<sup>American</sup> ~~Common~~ Naturalist, June and July 1896). The principle is well explained by Lloyd Morgan in his recent book on Animal Behaviour. "<sup>Granted</sup> ~~Indeed~~", he says, "that acquired modifications, as such, are <sup>not directly</sup> ~~most directly~~ inherited, they may none the less <sup>afford</sup> ~~affect~~ the conditions under which coincident variations escape elimination". By coincident variations he means "those, the direction of which coincides with that taken by the modification". "Survival would in the long run be better secured, we may suppose, when the two methods of adjustment are coincident and not conflicting". The acquired variations will keep the individual, and preserve them until some congenital variation shall arise which is coincident in direction and of a similar adaptive value. Thus though the

acquired variations are not themselves inherited they play an indirect part in the origin of species in as much as they act as a shield favouring the origin and growth of such congenital variations as are appropriate to the habit. It has been suggested that we may find in this so-called "organic selection" an explanation of the origin of co-ordinated structures which has proved such a stumbling block to those who like Weismann believe in the "all-sufficiency" of natural selection. It <sup>also</sup> makes it possible for us to understand how intelligence might become a factor in evolution. Intelligence often leads to the formation of new habits and thus to the development of acquired character. Any congenital variations which coincided in description with the modifications thus produced would be favoured and eventually preserved.

But it must not be supposed that biologists are yet agreed in throwing over the Lamarckian factors and in denying their transmissibility. The question is still an open one. It is true that many of the arguments generally adduced in favour of the inheritance of acquired characters have been found inconclusive, but some facts still remain which are difficult to explain without the help of such factors. The decision of the question is rendered very difficult owing to the fact that in the case of wild animals and plants it is almost impossible often to exclude the possibility of natural selection having

been at work.

At one time Brown-<sup>s</sup>Lequard's experiments on guinea-pigs were thought to afford ~~exclusive~~<sup>conclusive</sup> evidence in favour of the inheritance of acquired characters. But these experiments have ~~never~~<sup>never</sup> been verified and are ~~now~~<sup>now</sup> generally discredited by Zoologist Romanes in his Darwin and after Darwin (Vol.II.p.114) gives an account of some investigations which he carried on along the same lines. On the whole he found himself unable to furnish any approach to a full corroboration of Brown-<sup>s</sup>Lequard's results. It is difficult to believe that ~~mutations~~<sup>mutations</sup> are ~~now unlimited~~<sup>ever inherited</sup>, for though the Jews have carried on the ~~rite~~<sup>rite</sup> of circumcision for centuries no effect has been observed on succeeding generations. But as has been pointed out by Herbert Spencer (appendix Principles of Biology.p.631.) the inheritance or non-inheritance of ~~mutations~~<sup>mutations</sup> is beside the question. The fact that no evidence for such exist does not prejudice the question of the inheritability of characters acquired through functional changes.

Weismannists have ~~never~~<sup>never</sup> been able to meet satisfactorily the difficulty which arises in explaining the co-adaptation of cooperative parts unless the Lamarckian factors are called in. This difficulty has been well explained and exemplified by Herbert Spencer and by Romanes.. As Romanes observes "it belongs to the essence of co-ordination that each of the co-ordinated parts should be destitute of adaptive value per.se." the adaption only begins to arise if all the parts in question occur associated together in the same individual from the very first." Natural selection alone is not sufficient to account

for it. And it is doubtful whether the new theory of "organic selection" will ~~meet~~<sup>meet</sup> all the difficulties. The most recent of Weismann's theories, namely that which he calls "general selection" is an attempt in ~~fact~~<sup>part</sup> to ~~meet~~<sup>meet</sup> the difficulty and also to account for variations occurring in determinate directions. But we here enter the regions of pure speculation and it is therefore impossible to prove or disprove an hypothesis of this sort.

Another line of argument advanced by Spencer (Appendix to the Principles of Biology, Vol. I) and one which Weismann and his followers have failed to meet satisfactorily, is that derived from ~~Weismann's~~<sup>Waller's</sup> experiments on the sense of touch. The unlikeness of tactual discriminativeness displayed by different parts of the body-surface can be expressed by actual measurements. It is very difficult to explain by natural selection how such a distribution of tactual perceptiveness as is found can have arisen. But if the effects of use are inherited, the facts can be readily accounted for: it is well known from observations made on the blind ~~that~~<sup>that</sup> the constant exercise of the tactual nervous structures leads to their further development. The same result is well shown in the fingers of composers. — A case which has been considered by Weismann(+) to afford a very good test is that of the progressive degradation of the human little toe. This had been ascribed by some of those who hold Lamarckian views to the ~~unheralded efforts~~<sup>unheralded efforts</sup> of ~~the~~ constant boot-pressure. Weismann was able without much difficulty to overthrow this argument. For a

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(+) The All-Sufficiency of Natural Selection (Contemporary Review, 1893).

similar degradation of the little toe is seen among people who always walk bare-foot. But Spencer has shown that the alteration in the little toe has its origin not in the effects of boot-pressure but in the modification in the form of the foot which has been brought about as a result of the change from ~~arboreal~~ habits to terrestrial habits which took place ages back during the genesis of the human type from some lower type of primates. A consequence of this change of habit has been that the inner digits of the foot have gradually increased and developed while the outer digits have dwindled. In walking the great <sup>in</sup> stress is thrown by man on the inner sides of the feet and so the inner digits have come into more use as compared with the outer digit. The inheritance of the effects of this use and ~~decrease~~ <sup>decrease</sup> of parts accounts for the present form of the toes.

Spencer is not so fortunate in another piece of evidence which he records from the anatomy of the human body. In the Journal of Anatomy and Physiology (Oct. 1893 and April 1894) Dr. Havelock Charles contributed papers setting forth some of the differences he had observed between the leg-bones of Europeans and those of the Punjaub people. The differences noted were seen in the knee-joint and ankle-joint and are ascribed to the fact that the Punjaubi always squat on the ground and never sit on chairs as the Europeans do. Certain facets are seen on the bones of the Punjaubi and these have been produced by the action of

certain muscles which are brought into use in squatting. These facets are not found on the bones of adult Europeans. As Dr. Charles found that those facets are well-marked not only on the leg-bones of adult Punjaubi but also on those of the infant or foetus he concluded that those markings are instances of the transmission of acquired characters. The total disappearance of the markings on the European skeleton is ascribed to the change of habit as a result of which the possession of the facets would be of no advantage. But he does not appear to have examined the European foetus-in-utero and this is the weak point in the argument. Professor Macalister has shewn to the writer from specimens preserved in the Anatomical Museum at Cambridge, that the facets on the tibia where it fits on to the astragalus and which are supposed by Dr. Charles to be a peculiarity of the tibiae of the Punjaubi are seen also in the foetus of the European. The only legitimate induction which can be drawn from these differences is therefore that the facets disappear in the adult European through disuse. There is no evidence to show that there is any transmission of acquired characters.

Numerous cases have been recorded by botanists and zoologists of what they regard as genuine cases of the transmission of characters which have been acquired by the individual. Eimie<sup>r</sup> in his book on Organic Evolution brings forward many instances. But in the majority of these one cannot exclude the possibility

of natural selection having been concerned in the process and so the proof is not conclusive. A striking case is given by Mr. Gadow in the Proc. Royal <sup>Inst.</sup> Academy (Vol. II. No. 2). He there describes the Crop and Sternum of Op<sup>h</sup>stocomus Cristatus. This bird has a peculiar alimentary canal, the gizzard is much reduced in size and strength and the function usually performed by it has been assumed by another organ, the Crop which has consequently also become modified in a peculiar fashion. The wide and thick-walled crop rests directly upon the breast-bone. This has resulted in the ~~distortion~~ <sup>distortion</sup> of the skeleton parts of the bird such as the <sup>r</sup>ecession of the ~~heel~~ <sup>heel</sup> and the depression of the ~~furcula~~ <sup>furcula</sup>. An examination of the embryo proves that these changes take place at an early date. With regard to the ontogenetic development Mr. Gadow says that "the crop assumes its peculiar shape at a very early period, certainly long before it can be functional". And, again, he adds "although we see that, <sup>and</sup> how the crop, by its downward growth, gradually encroaches upon and modifies the conformation of neighbouring organs, some of these modifications of the sternal apparatus are already <sup>pre</sup>formed to a considerable extent, before they are actually necessitated. They are <sup>unbounded</sup> ~~unbounded~~." He concludes that "the embryonic development of the Hoaz<sup>in</sup> shows a faithful, but slightly condensed, repetition of those changes which its ancestors have acquired through adaptation to a peculiarly isolated life and diet".

If it could be taken as an absolute certainty that the modifications in the crop resulted originally from changes due to adaptation to new conditions of life and that the skeletal peculiarities have resulted from the alteration in the crop, then a case of this kind would be decisive. For the fact that these characters are now developed in the embryo before there is an opportunity for the modifications to occur through use and disuse of parts, proves that they are no longer produced in each individual independently as a result of functional changes in its own experience and that characters which were originally acquired by the ancestors of those birds have now through inheritance become congenital in the race.

An objection often urged against the belief in the inheritance of acquired characters is that it is difficult to conceive how changes in the soma can affect the reproductive cells in such a way as to bring this result about. But this is no valid argument, for the question can only be settled by an appeal to facts. The microscopical examination of the tissues of plants and animals has during recent years resulted in the discovery of a state of things which tends to remove this difficulty. The cells composing the organisms have in numerous cases been found to have connections with each other by means of protoplasmic threads. This was first of all noted in the sieve tubes of plants, and afterwards the same was found to be true



in other cells of the plant tissues. Gardiner in a paper on "The Histology of the Cell-wall with special reference to the mode of Connection of Cells" (Proc. Roy. Soc., 1897) has shewn this to be the case and another paper <sup>read</sup> ~~approved~~ by Gardiner and Hill (Trans. Roy. Soc., 1901) in which those observations are confirmed and extended. Similar facts have been recorded in animal tissues as for instance by Mr. Adam Sedgwick in his Mono-graph of the Development of ~~Serapentes~~ <sup>Variscus</sup> Capensis. It is questionable whether we are any longer justified in speaking of cells at all. The fully segmented ovum is a syncytium and it is probable that this syncytium is maintained throughout life. This seems to show that there is a closer connection between the reproductive elements and the soma than Weismann has been willing to allow. And it suggests to us a possible way by which influences might pass from the body to the reproductive organs. Indeed, evidence can be brought forward to show that influences do occasionally pass from the soma to the reproductive elements. Young in his experiments on tadpoles found that by altering the quantity and quality of the food he was able to alter the percentage of females produced. Evidence has also been adduced to show that in some cases the influences may pass the other way, namely, from reproductive elements to the body. ~~Presley~~ <sup>Presley</sup> places great faith in the phenomenon known as "Telegony". Spencer and other Lamarckians have hailed this phenomenon as an indisputable

proof of the inheritance of acquired characters. The well-known case of the horse and the quagga brought forward by Lord Morton was the first to attract the attention of scientists. Other examples which were supposed to show a similar influence were soon forth-coming and Spencer even quotes cases furnished by the offspring of whites and negroes in America. A question of this sort can only be decided by experiment. Professor Corsar Ewart has for many years conducted a series of experiments on the Equidae and other quadrupeds and birds, with a view of testing this point. His results, which are given in the work already mentioned, have been purely negative. No such thing as telegony has been observed. So the supposed influence of a sire on the progeny produced by the same mother to another sire has yet to be proved.

A somewhat similar phenomenon has been stated to occur in plants. Darwin in his Animals and Plants under Domestication (Vol.1) quotes instances in which the male element has had a direct action on the mother-plant. To this action the name of "Xenia" has been given. It is probable that such action does occur but it is not yet proved that future offspring are affected in any way.

Reflex actions and instincts present many difficulties to those who deny the inheritance of acquired characters. As pointed out by Romanes "it belongs to the very nature of reflex action that it cannot work unless all parts of the machinery concerned are already present and already co-ordinated in the same

organism". It is difficult to see for instance, how the extraordinarily co-ordinated actions displayed by a frog after its cerebrum is removed and when it is forced to balance itself on a moving surface, can be explained unless the Lamarckian factors have had something to do with their origin. Darwin and after him Romanes called in the principle of what was termed by G.H. Lewis "lapsing intelligence" in order to account for some instincts. Romanes distinguished instincts which arose in this way as "secondary"; reserving the term "primary" for those whose origin can be fully explained by natural selection. It is generally admitted that natural selection is inadequate to account for all instincts and in order to get over the difficulty the principle of "organic selection" has been called in. But this has one great drawback - it requires an enormous range of time. Though the inheritance of acquired characters has not yet been proved, it cannot be said to have been disproved. Perhaps ~~it~~<sup>it</sup> is impossible but it is important to note that there are phenomena for which no satisfactory and full explanation can be found unless the Lamarckian factors are allowed to have had a share in the process of organic ~~isolation~~<sup>evolution</sup>.

vigour of the offspring would be required. This again would not be a case of the inheritance of acquired character. Dr. Hamilton Much has been written on the influence of Heredity in disease. The vast majority of medical men still hold to the opinion that acquired characters are transmissible in inheritance. Thus the short-sightedness which is so prevalent in Germans and which is now a congenital character is said to have been brought about by the inheritance of the results produced by the constant reading of small print. The transmission of nervous peculiarities has also been often alleged and is strongly believed by Dr. Hughlings Jackson, Dr. Clouston and other specialists. At any rate the development of the musical and aesthetic faculties is felt to be difficult to explain by natural selection alone for it is not easy to see how advance along these lines would favour the survival of the individuals in the struggle for existence.

An interesting paper on "Heredity in Disease" by Professor Hamilton occurs in the Trans. Medico. Chir. Soc. Edin. (Vol. XIX. New Series) a discussion by medical men follows. It is pointed out that toxic diseases may infect the germ-plasm directly and are therefore irrelevant to the question at issue. Again touching the question of a predisposition to drunkenness it is pointed out that the germ-plasm may become poisoned by the alcohol saturating through the body. In such a case the

vigour of the offspring would be impaired. This again would not be a case of the inheritance of acquired character. Dr. Hamilton arrives at the conclusion that "the various hereditary tendencies or predispositions to disease of the hereditary type has arisen as variations in the germ-plasm". He thinks that the gouty habit of the body arose in this way, and that the predisposition to tuberculosis which is often seen is due to a vulnerability of the protective epithelia, and that this also has arisen as a variation in the germ-plasm. He explains the origin of mental diseases in a similar way. He adds that "there is no evidence proving that diseased conditions of body, excited by external agencies, using the term in its broadest sense, can be transmitted hereditarily through generations". That is to say he agrees with Weismann and his followers. But it is evident from the discussion which followed that medical men are by no means unanimous on this question. The majority cling to their belief in the Lamarckian factors.

The only safe conclusion to which we can come is that the question as to inheritance of acquired characters has still to be answered.

Evolution depends on Variation and Heredity. The problems of Variation and Heredity are now being attacked from many sides by biologists. It is on their solution that all advance in future must depend. To propound hypothetical speculations and to marshal arguments for and against certain views no

longer satisfy the enquirer. He wishes to ascertain what are the facts. Speaking at the British Association in 1897 Sedgwick says, "The phenomenon of genetic variation forms the bed rock upon which all the theories of evolution must rest, and it is only by a study of variations, of their nature and cause, that we can ever hope to obtain any real insight into the actual way in which evolution has taken place". Reference has already been made to the useful and promising work that is already being done on the study of variations. An important field of enquiry is to find out what is the effect of changed conditions in asexual reproductions. For here there is an opportunity of studying the result of the <sup>action</sup> ~~scheme~~ of modification <sup>on</sup> and the reproductive system without the complications introduced by the act of conjugation.

Some advances have been made also in regard to the problems of Heredity. Galton in his Natural Inheritance has by the application of statistical methods to large populations through many generations shown that there is a law of regression by which there is a tendency to maintain an average set of characters in the stock. He has also enumerated a law of Ancestral Inheritance (Proc.Roy.Soc.Vol.61) according to which the contribution of each progenitor to the total heritage of the offspring is calculated. This law has been corroborated and slightly corrected by Karl Pearson (Proc.Roy.Soc.Vol.62). These are the first systematic attempts to <sup>uncover</sup> ~~enumerate~~ laws of heredity

De Vries and Bateson have also called attention lately to the remarkable work done by Mendel so long ago as 1865. He carried out a series of experiments in crossing <sup>Banister's</sup> ~~hybrids~~ <sup>Pisum</sup> of ~~Pisum~~ <sup>sativum</sup>. Seven pairs of characters were selected, "a large number of crosses were made between ~~Parents~~ <sup>Parents</sup> differing in respect of each of those pairs of characteristics. It was found in each case that the offspring of the cross exhibited the character of one of the parents in almost undiminished intensity, and ~~in some cases~~ which could not be at once referred to one or other of the parental forms were next found." The account of these experiments is given by Bateson in a paper on Problems of Heredity in the Journal of the Royal Historical Society, 1900 and since that time Mendel's original paper has been reproduced. "In the case of each pair of characters there is one which as the first cross prevails to the exclusion of the other. This prevailing character Mendel calls the dominant character, the other being the recessive character". The interesting point is that ~~it~~ <sup>it</sup> was found that by self-fertilizing the original cross-breeds the same proportion was always approached - the proportion being 1 Dominant  $\neq$  2 cross-breeds  $\neq$  1 <sup>recessive</sup>.

The same numerical law followed in each generation.

It is seen that there is here a new law of Inheritance, which has since been called Mendel's Law. The full consequence of this discovery has still to be worked out and many

workers are busy following up Mendel's observations.

Variation and Heredity are ultimately based upon the  
prop~~ositions~~<sup>erties</sup> of protoplasm and so all the work that is now being  
done on ~~Zoology~~<sup>Cytology</sup> as well as that on Developmental Mechanics  
<sup>also</sup> will help to solve the problems of Evolution.

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