exchanged visits with the Gaekwar, and drove through the native city to the old Palace.

But all this official programme did not satisfy his Royal Highness. Intuitively he perceived that something more than official formalities was expected of him. Hindu public opinion was all in favour of the Maharani Jumna Bai previously mentioned. Though her grievances against the Baroda Durbar were redressed by the Government of India, yet she had received no consolation for which the heart of a woman always craves. In official red-tape there is not much room for sentiment, and with a woman a little sentiment is of more value than all the Resolutions of the Government put together. It was left to his Royal Highness to find out that the Maharani Jumna Bai wanted something more than official reparation. He at once made up his mind to pay her a visit. This was no sooner thought of than done. The shortness of the time required immediate action. Its effects were magical. All the bad blood caused by recent incidents was removed. Even the sullen Sirdars, who did not hesitate to ascribe motives to the British Government for interference with the affairs of Baroda, were appeased. Even the adherents of Ranis Mahalsa Bai and Lakshmi Bai could not help praising the Prince as a great peacemaker. The Maharani Jumna Bai made thank-offerings at the temples of her faith. Travelling pilgrims carried the news from shrine to shrine. All Hindu India echoed with the praise of the Prince. Bards in different parts of India vied with one another in singing his virtues. Hindu astrologers made themselves busy in casting the horoscope of his Royal Highness. His fame travelled faster than the special train which carried him, and reached villages and out-of-the-way places where no newspapers circulated. For the first time the people of India felt that British policy was not confined to physical possession of the country, but was extended to holding the hearts of the natives of India. This policy was initiated in the most unobtrusive manner by one who was destined to be the first Christian Emperor of India.

In my next article I shall be able to show how the Prince's progress in Upper India produced a wonderful effect in the Provinces which not many years before had been the arena of mutiny and massacre.

S. M. MITRA.

THE RESPONSE OF THE ANIMALS TO THEIR ENVIRONMENT

III

Let us now examine some of the experiments that were made upon the much higher division of vertebrates, in order to see how their forms and structures could be altered under the direct action of new surroundings. Several such experiments were made with success upon amphibians, among which there exists, as is known, a certain variability in the manners of life, aquatic and terrestial, as also in the modes of reproduction—both accompanied by notable changes in the structure and the forms of these animals.

The Mexican Axolotl, or Siredon, is especially worthy of note in this respect. It is known that this inhabitant of Mexican lakes is a newt-like creature, from 8 in. to 10 in. in length, of a dark grey colour, with black spots, but that it retains, even in its adult age, three pairs of branched external gills—which feature led Cuvier to suspect that the Axolotl represents nothing else but the undeveloped stage of some salamander. But, as it lays eggs and reproduces itself even in this imperfect stage, and the explorers said that it never had been seen in Mexico to undergo metamorphoses, zoologists described it as a special genus of lizards. It was only in 1865 that A. Duméril saw in the Jardin des Plantes at Paris that some young ones, born from his Axolotls, lost their external gills, the gill-clefts closed up, the fins along the tail and the back disappeared, and all the shape of the animal was changed. Its head became broader, the tail became thicker and nearly cylindrical at the base, and the colour of the animal changed; yellow spots covered it. In short, it turned into a well-known salamander, the terrestrial Amblystome.[1] Cuvier was right; the Axolotl represents nothing but the undeveloped stage—the incomplete metamorphosis of the Amblystome; but, like several other animals, it is capable of reproducing itself before it has

[1] *Amblystoma tigrinum.*

accomplished its metamorphosis. It appeared also that, out of the eggs laid by Axolotls, some would grow as Axolotls and some as Amblystomes; while out of the eggs laid by the latter some would give Axolotls and some would give Amblystomes, according to the surroundings in which they are kept.

So long as it was thought that in Mexico the Axolotls are never metamorphosed into Amblystomes, various hypotheses were made (among others by Weismann) to explain how the Axolotls might have been evolved during the diluvial period as a 'retrogressive form' of the Amblystome. But now it is generally known, since 1882, from the work of José Velasco, that the Mexicans are quite familiar with both forms, the Axolotl and the Amblystome, and that each year, when the lake of Santa Isabel dries up, the Axolotls it contains undergo the salamandra metamorphosis. The same takes place even in lakes which never dry up entirely, and where the Axolotls could have found all the conditions (pure water, abundant food) for thriving well.[2] It thus becomes probable that it is the influence of environment which hampers the transformation and produces what biologists describe as neotenia—*i.e.* sexual reproduction taking place before the fully adult stage has been reached.

Seeing that during the metamorphosis of the Axolotl into an Amblystome the main point is the transformation of its respiratory organs from external gills to internal lungs, and the passage of the animal from an aquatic to a terrestrial life, A. Duméril tried to provoke the metamorphosis by cutting off the gills; but he obtained nothing conclusive. Weismann, who tried to compel Axolotls to live on land, came to negative results. However, Mlle. de Chauvin, who continued his experiments, succeeded—perhaps because she began by giving her animals an abundance of food. All the Axolotls she experimented upon took to a terrestrial life and were transformed into Amblystomes.[3]

Dr. R. W. Shufeldt continued these experiments in New Mexico,[4] and found that the Axolotls accomplish the metamorphosis more readily if they are kept in water imperfectly aërated; also when they are young and when they are supplied with plenty of proper food. When they were well fed with meat the Amblystomes 'were not only larger, but of a very deep, muddy black colour without spots, while the others were mottled with bright yellow and a pale brown' (p. 263). The deeper the water, the

[2] *La Naturaleza*, t. v. 1880-81. I follow the summary of these researches given by Professor Blanchard.

[3] *Zeitschrift für wissenschaftliche Zoologie*, Bd. xli. pp. 365-389. It is a quite remarkable work, during which Mlle. de Chauvin already transformed at will Axolotls into Amblystomes, and provoked a beginning of return of the latter to the primitive form.

[4] Letter to *Science*, vol. vi. 1885, II. pp. 263-264.

slower the metamorphosis—possibly in consequence of the diminished chance of using their lungs, while a moderate increase of temperature seems to hasten the transformation.

And finally, we have the recent experiments of M. P. Wintrebret. After having experimented upon Axolotls for several years, he obtained at last half-metamorphosed creatures which stand half-way between the Axolotls and the Amblystomes. He placed Axolotl larvæ in an atmosphere of moist air, and found that they could live in it and that finally they underwent the usual changes—that is, an atrophy of the larval organs which they used no more, namely, the gills, the caudal fins, and the web between the digits.[5] They thus became like Amblystomes. Then M. Wintrebret put these young half-metamorphosed Axolotls into water, and there their branchial filaments reappeared gradually, and the animals took on the darker colouring of the Axolotl; but at the same time they retained the other characters of the Amblystome. The skin and the respiratory organs thus proved to be more easily affected by a change in the environment than the skeleton. Here, again, we have, then, a considerable structural change, formerly attributed to an extremely slow process of natural selection which would pick out accidentally produced variations, but it is produced now, experimentally, in a very short time by the direct action of surroundings.

The influence of environment upon the process of transformation and the sexual generation in the salamander is equally significant. We have in Europe two species of salamander—the Spotted or Fire Salamander (*S. maculosa*), which is found everywhere in Central Europe and North Africa, and the Black Salamander (*S. atra* or *S. Nigra*), which is found in the higher mountains of Central Europe, and totally differs from the former by its mode of reproduction. The Spotted species always lays its eggs in water, and gives origin to from fifteen to twenty (occasionally as many as seventy) tadpoles, which have external gills and caudal fins. As soon as they have broken the shells of their eggs they begin to swim. For several months they lead an aquatic life; then they gradually lose their gills and the fins along the tail, and become ordinary terrestrial salamanders, breathing with their lungs and possessed of a nearly cylindrical tail. As to the Black or Mountain Salamander, it usually gives birth to two young ones, which represent a far more advanced metamorphosis; they have neither gills nor fins, breathe with their lungs as soon as they are born, and in all respects are like adult Black Salamanders. They also go through a certain metamorphosis, but they

[5] 'L'adaptation au milieu,' in *Comptes Rendus de la Société de Biologie*, November 1908, t. lxiii. p. 521. The results are very much like those obtained by Mlle. de Chauvin.

accomplish it in the body of their mother—two individuals living upon the substance of the other eggs.[6]

In the intermediate zone of altitudes, from 800 to 1200 mètres, one meets with a series of intermediate forms of reproduction. Thus, Kammerer found in the lower altitudes Black Salamanders giving birth to two more young ones, born a little before time, but still capable already to live on land. And he found in the higher altitudes the Spotted Salamander giving birth to a few highly developed larvæ, which had fed before birth upon the contents of the other eggs.

It was natural, therefore, to try to modify the mode of propagation of these two species of Salamander by modifying the conditions of their life, and this is what Prof. P. Kammerer, who works with Dr. Przibram at the Laboratory of Experimental Biology at Vienna, tried to attain. Such experiments were the more necessary, as Weismann, after having made experiments upon the water-fleas (*Daphnias*), had come to the conclusion that external conditions have but little or no influence upon the kind of reproduction; while Issakowitsch, working under the direction of R. Hertwig, had come, also for *Daphnias*, to the quite opposite result.[7]

It was not easy to induce the Fire Salamander to breed in confinement; but finally this was obtained by keeping it at a low temperature and in surroundings where there was no water basin —thus depriving it of the possibility of laying its eggs in water. Most of the embryos degenerated, but finally, after the female of the Fire Salamander had got into the habit of laying late, it gave birth to two fully developed, dark individuals, just like the Black Salamander. The reverse result was obtained by experimenting upon the Black Salamander. When the latter was kept in a warm temperature, near to a basin of water, it gave birth to more than two young ones, and these young lived in water and had all the characters of the Spotted or Fire Salamander.[8]

These results are already most valuable, but Kammerer further increased their value by proving that when the mode of reproduction of the Black Salamander has once been changed, and, after having been kept for some time in unusual surroundings it has taken to the mode of reproduction which is characteristic for its Spotted congener, its descendants continue to give birth to their young in the same fashion, even after they have been returned to their normal conditions of life.

In 1904 Dr. Kammerer had concluded his work by asking himself whether, after he had accustomed the Fire Salamander to

[6] P. Kammerer, in *Archiv für die Entwicklungsmechanik*, vol. xxv. pp. 8-9.

[7] For the discussion of this last question see chapter xxi. of Professor Th. H. Morgan's *Experimental Zoology*. Also chapter xix.

[8] *Archiv für die Entwicklungsmechanik*, vol. xvii. 1904, pp. 165-264.

the mode of propagation of the Black species, and *vice versâ*, the new reproduction habits would be transmitted to posterity? Continuing accordingly his experiments,[9] he tried to accustom the Black species to lay its young ones in water, in the shape of larvæ, after the mode of its Fire congener. This proved to be very difficult. However, starting from the idea that the Black, or Alpine, Salamander must have acquired its habit of giving birth to fully developed terrestrial salamanders because she could not find in the high mountains the quiet, not running, water which she needed, nor could she find a sufficiently warm water, Dr. Kammerer, in his second series of experiments, placed his Black Salamanders in such surroundings that they had no dry ground. And when they had once laid their young ones in such surroundings he simply kept them in a terrarium, with a wet ground and with a basin of water by its side. Then he accustomed these animals to live in a higher temperature, of 77° to 86°, and in these conditions the Black Salamander females took to the habit of early giving birth to an imperfect progeny of larvæ, like the Fire Salamander.

As to this latter, it was sufficient to take away the water basin of the terrarium, and to keep the females in a cellar at a *low* temperature (of 35° to 39°) during the winter, and in an empty water tank in the summer (at 54°), to retard the birth for three to four months. However, the low temperature had also retarded the development of the embryos, and all that Kammerer obtained was to have larvæ somewhat *more* developed than in the normal conditions. These larvæ, obtained under the effect of a *lower* temperature, were in about the same stage of development as the larvæ of the Alpine Salamander, obtained under the effect of a *higher* temperature (xxv. 20).

It is worthy of note that, once the Fire and the Alpine Salamanders had been brought to the above-mentioned new habits, the severity of the experiments which had provoked these changes 'could be relaxed without the above-mentioned changes in the mode of propagation being lost, or only reduced, in the next propagation periods.'

As to the experiments upon the inheritance of the acquired characters, they gave complicated results, so that the original memoir of Dr. Kammerer must be consulted. The following summary, in his own words, will, however, give an idea of the main results:

(*a*) An inheritance of the artificially produced change in reproduction took place in each case; (*b*) when the second generation was returned to its original conditions of life, the change was maintained, but in a weakened

[9] 'Vererbung erzwungener Fortpflanzungsanpassungen,' in Roux's *Archiv*, t. xxv. pp. 7-51, with plates.

degree—the more weakened the more time had passed between the return to the original surroundings and the delivery; and (*c*) if the changed conditions of life were maintained, the change in reproduction was maintained in the second generation, either in the same or in a stronger degree. (Pp. 48-49).

As might have been expected, the usual objection, according to which the changes produced and inherited in the salamanders might have been mere atavistic returns to previous instincts, has of course been made—namely, by Dr. Plate.[10] But, as Kammerer had already mentioned, this reproach could be applied only to one of the two series of his experiments, in which the highly differentiated mode of reproduction of the Black Salamander was changed into the lower mode of reproduction of the Spotted Salamander. Consequently, to explain the inheritance of the changed mode of reproduction in the latter, Plate had to make suppositions concerning the geographical distribution of the species which do not seem very probable, and to which Kammerer has easily replied. (P. 524 of same volume of the *Archiv.*)

In a recent work Kammerer gives the results of his further experiments upon the transformation of reproduction habits—this time in the well-known *Alytes obstetricans*. This little grey and spotted frog, which stands between the frogs and the toads by its forms and by the warts which cover its body, usually lives in colonies on dry land, in long burrows. It is very common in France, and is known for its sonorous voice and the sort of harmony which results when many individuals of different ages are singing at night, sounding each one its own note. The female lays its eggs in long strings, 2 and 2½ feet long, and the male assists the female to get rid of the eggs. After that, it is the male alone which takes care of the eggs. It goes to its burrow, but comes out every evening to find its food, and carries about the eggs, attached to its thighs, apparently without being hampered by them in its movements.[11] When the eggs are matured, the male enters some pool; there the eggs burst, and the tadpoles begin at once to swim about in search of food. These are, then, the reproduction habits which Kammerer undertook to alter.

In confinement the female of the *Alytes* maintained its habits—so long, at least, as the temperature did not exceed 62.5° Fahr.; but once it exceeded this limit, important changes took place in the mode of reproduction, the chief of them being that the female laid its eggs in water, and there they were abandoned to themselves. The care usually taken of them by the male, and which gave its specific name to the *Alytes obstetricans*, disappeared.

The descendants from these eggs offered no deviations from the normal animals. But if reproduction without nursing care became *habitual*, then both sexes preferred to meet in water. As to the individuals born without paternal care, they always laid their eggs in water, if the conditions of the experience (raised temperature, &c.) were maintained. Several other important details were noticed, but I must refer the reader to the original memoir of Kammerer. I give only his main conclusion—namely, that 'the inheritance of the enforced change in the mode of reproduction and development took place: (*a*) in each case when the parents had acquired a standing (*immanente*) variation of the instinct; and (*b*) where the germ-plasm could be acted upon during its maturing period by the altering influences.'[12]

We have thus a new proof of the considerable influence of the external conditions upon the mode of reproduction, which influence was contested by Weismann and his school. Besides, we have also in Dr. Kammerer's work the confirmation of a new principle which, I believe, is being brought more and more into prominence by modern research—namely, that one of the conditions for the hereditary transmission of an acquired character is that the modifying influence to which this character is due should act upon the individual when *in its embryonic stage*. Of course, till now this is only a hypothesis, which has a certain degree of probability, but has yet to be submitted to the test of experiment on a wide scale. But of this I shall have to say more on a future occasion, when I discuss heredity.

IV

Of the many experimental researches that are made at the Vienna Laboratory in order to throw some light on the debated questions of the theory of evolution, those of Dr. Przibram deserve special mention. They were made on the well-known Hermit crabs, which dwell, as is known, in the shells of various molluscs. If the shell into which the crab has lodged its posterior parts be cautiously removed, one sees that the abdomen of the crab has the aspect of a swollen glossy sack, totally unprotected, covered only with a very thin skin, through which the viscera are seen, and upon which no segmentation can be detected, unless one resorts to the magnifying lens. And yet, it appeared from Dr. Przibram's experiments, that it was sufficient to leave the crabs divested of their protecting shells, for one month in water, to see the abdomen becoming shorter and flatter, its skin taking a rougher and harder structure, and the segmentation of the skin becoming quite apparent. The whole aspect of the animal is

[10] Roux's *Archiv.*, xxviii. p. 524.

[11] F. Lataste, quoted by E. Sauvage.

[12] 'Vererbung erzwungener Fortpflanzungsanpassungen,' iii. in Roux's *Archiv*, vol. xxviii. pp. 447-546.

thus changed. With the *Eupagnus* crab, whether the individuals experimented upon be kept in full light or in the dark, patches of dark pigment rapidly develop on the hard skin which begins to cover the abdomen.

These results, Dr. Przibram remarks, have a considerable theoretical importance. In fact, the Hermit crab has over and over again been represented as a striking illustration of the effects of natural selection. Weismann especially made much of it. Speaking in 1892, in one of his *Essays upon Heredity*,[13] of the atrophy of organs which are no more useful to animals, he was quite positive in maintaining that only on the hypothesis of natural selection, supported by his hypothesis of 'universal crossing,' or 'panmixia,' was it possible to explain the process of degeneration of such organs as the hard integument in the Hermit crab, in the aquatic larvæ of the caddis-flies, and in the larvæ of certain small moths protected by their sheaths. However, Dr. Przibram's experiments on the Hermit crab throw considerable doubt upon these views. Altogether, we have learned lately, and some examples of it are given in the preceding pages, that changes attributed formerly to the extremely slow action of natural selection are easily produced under the influence of a changing environment, both in natural conditions and in experimental conditions imitating the natural ones, *within the short lifetime of the individual*, and this undoubtedly upsets the speculations which were so readily made twenty years ago.

> The rapid return [Dr. Przibram writes] of the abdominal tegument of the Crustacean to its primary condition testifies loudly enough that in the normal Hermit crab we have only the hampering of a capacity of development which still remains, but not a loss of that capacity in consequence of natural selection. When Weismann tries to explain retrogression by 'panmixia' and 'germinal selection,' he has against him the fact that the reaction he speaks of is produced *at once*, to a certain amount in the same individual.[14]

Unfortunately, Dr. Przibram continues, the question 'as to whether a hereditary transmission of such changes in the tegument of the crab's abdomen is possible, is not yet solved,' because the explorers have not yet succeeded in breeding Hermit crabs in confinement; 'but,' he adds, 'after the hereditary transmission of acquired characters has been proved in other classes of animals, it seems not improbable that already in the first generation we may obtain considerable changes, as they would be due in this case to alterations in the interchange of matter (*Stoffwechsel veränderungen*) in the organism.'[15]

[13] Vol. ii. p. 16.

[14] Roux's *Archiv*, t. xxiii. 1907, pp. 584 *sq.*

[15] *Loc. cit.* p. 593.

V

That changes in the conditions of life produce deep alterations not only in the outer appearance of animals, but also in the composition of their blood, and that these alterations necessarily must influence the rapidity and the very substance of all life-processes, is now proved by direct observation on rabbits taken to high altitudes. A certain number of wild rabbits were taken in August 1883 by M. Muntz to the Observatory that was built on the summit of the Pic du Midi, at an altitude of 9500 feet above the sea-level, where the average barometric pressure is only a little over twenty-one inches. The rabbits supported the change very well; they fed splendidly and bred as well as they do in the lower plains. Seven years later, in 1890, they were carefully examined, and it appeared that those which were born at the high-level station already differed a great deal from those which had been left in the plain. They were smaller, had less developed ears, and their fur-coats were already of a lighter colour and very thick. Their blood, too, had undergone a considerable change. It had become denser, contained more iron, and had a greater power of absorption for oxygen. Thus, it had an average density of 1060 in the Pic du Midi rabbits, and only of 1046 in the inhabitants of the plain; it contained on the average 70.2 milligrams of iron for each 100 grams of blood with the mountain-dwellers, and only 40.3 milligrams in the plain; and its power of absorption of oxygen was 17.3 cubic centimetres of oxygen per each 100 grams, as against 9.6 cubic centimetres for the low-level rabbits.[16] A similar increase was also found when sheep, born in the valley, were taken to an altitude of 8200 feet, and M. Viault, who analysed their blood, proved that the change was due to an increase in the numbers of red corpuscles. Life at a high altitude had thus an effect similar to that which is obtained by increasing the quantity of food.

The results obtained in this case and the preceding were evidently due to several causes besides mountain air, such as the quantity and the quality of absorbed food; and no discrimination was made between the effects of these different causes. But what imports us most in this case is to show that the external changes produced by a change of environment are due to such a deep cause as changes in the physical, chemical and physiological composition of the blood. Such changes cannot but exercise their effect on the whole of the organism, including its reproduction processes and its germinal plasm.

[16] *Comptes Rendus*, t. cxii. 1891.

I am compelled to omit many other interesting works in the same direction. But it is necessary to mention, be it only in a few words, some less-known modern investigations of Edw. Babak, W. Roux, and E. Schepelmann into the influence of various sorts of food upon the digestive tube and other organs of animals. These extremely complicated researches are not yet concluded; but, being conducted in physiological laboratories by experienced physiologists, they promise to yield most valuable data for the knowledge of variation due to the use and disuse of different organs and the conditions under which such variations may be inherited.[17]

It was already known from the experiments of Weiss and those of Houssay[18] that considerable changes had been produced in the digestive tube of chickens after they had been fed for four months with horseflesh, when Edw. Babak began a series of similar experiments on tadpoles. All such investigations offer great difficulties in the interpretation of their results, inasmuch as it appears from the work of Pawlow that different sorts of food not only produce notable changes in the strength of the gastric juice secreted after the absorption of a given food, but that they also call forth different secretions from different glands, so that their effects on the digestive tube are not merely physical but also chemical, or rather physiological. However, it was established with certainty by Edw. Babak's experiments[19] that a prolonged keeping of tadpoles on an exclusively vegetable food which could not be rapidly digested, by imposing more work on the digestive tube, led to an increase of its *surface* relatively to its inner volume.[20] And this increase is considered by Babak to be, as it certainly is, a proof of '*a direct* adaptation of the organism to a certain function, produced by the performance of this function.' It is thus one of those cases of which we saw several examples when we examined the adaptive changes produced in plants by placing them under new conditions of life. It is a case of 'functional adaptation,' which does not require that natural selection should pick out the most suitable variations out of thousands of indiscriminate variations: it is produced *in the individual*, in the

[17] Roux's *Archiv für die Entwicklungsmechanik*, vols. xxi. 1906, and xxiii. 1907.

[18] *Comptes Rendus*, t. cxxxv. 1902, p. 1357, and cxxxvii. 1903, p. 934.

[19] Roux's *Archiv*, vol. xxi. pp. 611 *sq.*

[20] Taking 1000 individuals, originated from six mothers, and keeping them in six different compartments of his aquarium on different sorts of food, Herr Babak found that the lengths of the digestive tube were 6.6 lengths of the body with the tadpoles fed on the meat of vertebrates, 5.9 when the food consisted of molluscs, 7.6 when it consisted of lobster, and 8.3 lengths when the food was entirely vegetarian albumen (*Beiträge der chemischen Physiologie und Pathologie*, 1905, Bd. vii.; summed up in *Naturwissenschaftliche Rundschau*, 1906, Bd. xxi.).

short interval of a few months, by the *direct* action of the new 'environment' (changed food). It is what Herbert Spencer so perfectly well described as 'direct adaptation,' in opposition to the 'indirect adaptation' through the intermediary of natural selection, and what W. Roux tries to explain through the 'struggle of the parts of the organism.'

It would be impossible to sum up in these pages the works of Roux[21] and Schepelmann[22] on the effects of various sorts of food on the digestive tube and the other organs of geese. Their results are too complicated. Suffice it to say that not only the digestive tube undergoes substantial changes (elongation and so on), but quite a series of alterations takes place in the accommodations of different portions of the digestive apparatus to different sorts of food. This important organ is thus endowed with an astounding variability. However, it was found that two different periods must be distinguished in the development of all organs: one period, when the auto-differentiation of the organ takes place in virtue of its inherited properties, and another, when the function it performs gives it its definite character. Besides, notable changes were found to take place in the quantity and the composition of the blood; so that, taking everything into consideration, new vistas are opened upon this question of use and disuse, and the ways in which the different effects of use and disuse may, or may not, be transmitted by inheritance.

VI

To give a complete idea of the animals' response to their surroundings, I ought also to analyse the investigations made into the changes produced by a changing environment in the colours and the markings of animals. It appears, however, that even a rapid review of the vast subject which I have written for this essay would double its size; so that I must give up for the moment the analysis of the variation of colours, and refer the reader to excellent reviews of the whole subject given by Professor Delage and M. Goldsmith, Professor Th. H. Morgan, and Dr. Plate in their above-mentioned books, and especially by Miss Newbigin in a special work devoted to colour in nature.[23]

Taking, then, those researches which deal with the experimental variation of form and structure in plants and animals,

[21] W. Roux, 'Ueber die funktionelle Anpassung des Muskelmagens des Gans,' in *Archiv für die Entwicklungsmechanik*, 1906, t. xxi. p. 461 *sq.*

[22] E. Schepelmann, 'Ueber die gestaltende Wirkung verschiedener Ernährung auf die Organe des Gans'; same *Archiv*, t. xxi. 1906, p. 500 *sq.*, and t. xxiii. 1907, p. 183.

[23] *Colour in Nature: a Study in Biology*, London, 1898 (John Murray). In 1901 I gave a brief introductory sketch of this subject in a 'Recent Science' article (*Nineteenth Century and After*, September 1901).

and of which some specimens have been given in this article and in the article on plants,[24] one must certainly confess that, although most of them were conducted with admirable skill, they nevertheless represent only the first steps towards the foundation of a new branch of science—*physiological* experimental morphology. This is especially true of the zoological works. Many earlier researches have, in fact, the character of a mere reconnoitring of the ground to be explored; and only the later investigators, by paying a special attention to the facts which throw a light upon the inner, physiological, and anatomical causes of variations, prepare materials for the solution of the question—whether these changes are not too superficial to be inherited?

And yet, taken as a whole, the experimental researches into Variation have already given two important results.

First of all, they have contributed to retain, and still firmer to establish, biology on its proper basis—that of observation and experiment. During the last twenty years we have had too many discussions about theories of heredity—too far-fetched, in the opinion of prominent anatomists, for the modest anatomical basis upon which they were built; and the result was that mere dialectics began too often to take the place of scientific generalisation and empiric research; and with a certain number of biologists one meets now, even in the fatherland of Bacon and Darwin, a painful neglect of experimental study in this field.

And yet those who pursue the experimental study of Variation are only continuing the studies that Darwin began when he spent several years on his great work *Variation of Animals and Plants under Domestication*, which had to be followed by *Variation in Nature*. They investigate, as Darwin did, how the different natural factors—temperature, moisture, light, food, overcrowding, and so on—affect, each one separately and all together, the forms, the colours, the organs, and the tissues of different organisms. Like Darwin himself, they are not afraid of the word 'Lamarckism,' when their researches confirm the views of Lamarck; they do not repudiate it for any theoretical or social reason, but they do not hold a brief for it. And they maintain that the last word as to the causes of variability and the inheritance of acquired characters will belong—not to theories about heredity, however clever they may be, but to *experiment*, to *empirical research into the causes of variation*. And in pursuing their laborious work they are far more true 'Darwinians' than those who, having once taken from Darwin his conception of Struggle for Life and Natural Selection, neglect now those experimental studies of Variation which he left unfinished only because of his failing health.

[24] *Nineteenth Century and After*, July 1910.

Those biologists who pursue the experimental study of Variation, hand in hand with the study of Variation in Nature,[25] have already established one important fact. They have proved that besides the accidental, 'indefinite,' and 'indiscriminate' variation, of which we do not know the causes, but which we can with some probability attribute chiefly to the vagaries of heredity, and which is kept, in its bulk, within certain narrow limits—there is variation which is *definite*, *discriminate*, greater in its effects, and to a very great degree *adaptive*. It is the variation which we saw, for instance, developing the organs of touch and smell in animals taken from an open pond and placed in the dark surroundings of the Paris *catacombes*; that sort of variation which changes in individuals placed in unusual conditions their ways of reproduction, in conformity with the requirements of environment; or alters the tissues, the outer form, and the assimilation powers of a plant, so as to make it better adapted than the mother-plant was to Alpine, or maritime, or desert surroundings. This part of Variation is a *physiological fact*. *It has its laws*, and these laws and their consequences modern biologists try to disentangle by experiment.

As to the objection which is now made by a considerable number of biologists—especially zoologists—namely, that these variations, provoked by the action of the environment, cannot be inherited, and that they could be inherited only if they were provoked by some unknown cause in times past, and, after having been dormant since that time as a potentiality in the germ-plasm, would be produced now accidentally, by inheritance—we shall examine this objection, which often takes the character of a mere doubt, on some future occasion.

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[25] I mean such works as those of Cope, Osborn, Hyatt, Willeston, Kellogg, Kölliker, and so on, on animals; and of Grisebach, Sachs, Henslow, Maheu, the Agricultural Experimental Stations, and so on, on plants.