CHAPTER XII.

RECAPITULATION AND CONCLUSION.

THE obscurity and complexity of the phenomena of heredity afford no ground for the belief that the subject is outside the legitimate province of scientific inquiry. The existence, in a simple and unspecialized egg, of the potentiality of a highly organized and delicately adjusted animal, with special functions, instincts and powers of adaptation, with the capacity for establishing and perpetuating harmonious relations to the changing conditions of the world around it, is certainly one of the most profound problems of the material universe.

The fertilized egg is one of the greatest wonders within our knowledge, but this is no reason for refraining from studying it.

If we believe that living things have become what they now are by a process of gradual evolution, and that they owe their characteristics to the influences to which they have been exposed in the past, we must believe that the properties of the egg are capable of explanation, as far as these determining causes are open to study.

If we accept the generalizations of modern science, and hold that an unicellular ovum is homologous with and is descended from a remote ancestral unicellular organism, and that its properties have been gradually acquired by the natural selection of favorable variations, we must believe that the origin of its properties is as much within our reach as the origin of species.

The most prominent characteristic of heredity is that it may be brought about not only by the various forms of asexual reproduction, but also by the sexual union of two reproductive elements, each of which is homologous with the other cells of the body.

In the lower animals and plants the cells which thus unite with each other, or conjugate, are similar in form, and probably in function also; but in all the higher organisms the male cell is very different from the ovum in form, size, and structure, as well as its mode of origin.

The present structure of each organism is the resultant of two factors, which we may call adherence to type and adaptation to new conditions, or if the use of terms without teleological implications is desired, we may speak of them as heredity and variation, or we may follow Haeckel and call them memory of past experiences, and perception of new relations. The precise terms to be used is a matter of little consequence. The essential thing is the recognition of the fact that each organism is the resultant *of two factors, and that evolution is two-sided.* An animal is what it is because it has the power to hold on to the experiences and adaptations which fitted its parents for their place in nature, and the parents acquired those peculiarities in virtue of their powers to gradually adjust their structure and habits to their environment.

This is the morphological side of evolution. Looking at it from its dynamical or functional side, we notice that each step in the process of advancement has been reached by divergent specialization and by physiological division of labor. Animals diverge from each other by acquiring the power to occupy different fields, to procure and use different kinds of food, to exist in different media, etc., and the organs and tissues and cells of a highly specialized animal or plant are adapted to perform definite, restricted functions exactly and efficiently, while each part of a low organism fills many offices, but fills them all imperfectly.

We find in all except the lowest organisms that heredity is brought about by two dissimilar reproductive elements, and we find that each organism is the resultant of two factors—heredity and variation.

It is natural to inquire whether there may not be some connection between these two relations; whether the natural selection of favorable variations has not acted upon the reproductive elements as it has upon the mature organisms; whether it has not brought about a physiological division of labor between these elements; whether their originally similar functions have not gradually become specialized until one has become the conservative *medium, and the other the agent of progress in heredity.*

According to the view advocated in this book, such has actually been the history of the evolution of sex, and natural selection has evolved, in all the higher organisms, a secondary law of heredity, which enables it to do its work rapidly and effectively, with little waste.

In the metazoa and in the higher plants, natural selection is not a crude, rough "hit or miss" method of evolution, for the law of heredity, itself a result of the law of natural selection, is that the ovum is the vehicle of heredity, while gemmules or cell-germs from cells in all parts of the body, are transmitted to the ovum by the male cell, thus causing variation when and where it is needed.

This view is opposed to the conclusion of many high authorities that there is no difference in the functions of the sexual elements, but examination shows that the reasons which they have given for this conclusion admit of another simple explanation.

Darwin's reason for his statement that each sexual element has the power to transmit every single characteristic of the parent form, and that it is an error to suppose that the male transmits certain characters and the female other characters, is that when hybrids are paired and bred *inter se*, the characters of either grandparent often reappear in the progeny.

A little thought will show that it is impossible to prove any such conclusion in this way. If two animals which differ from each other in every respect could be made to cross, the result would furnish conclusive evidence as to the correctness or incorrectness of Darwin's statement, but in any possible cross the parents are essentially alike, and they differ only in minor features of recent acquisition. The possibility of parthenogenesis proves that the ovum does transmit the entire organization, but it is impossible to show, from the phenomena of crossing, that the male element has the same power.

The reason given by Huxley for his opinion that an animal inherits every characteristic of each parent, is that the ovum and the male cell are homologous with each other, and that all the cells of the body are descended, by a process of division, from the compound germ which is formed by their union.

Homology, or similarity of origin, is no ground for assuming similarity of function, and the fact that the male cell and the egg are homologous with each other is no reason whatever for a belief that their parts in heredity are alike.

The fact that either sex may, under certain circumstances, acquire the secondary sexual characters of the other, seems at first sight to show that the whole organization of the male exists in a potential and latent state in the body of every female, and that the whole organization of the female is latent in every male; that each individual is a complete double person. If we accept this conclusion it is only logical to conclude that the power to revert or acquire the characteristics of remote ancestors proves the existence, in a latent state, in each individual, of the complete organization of each of a long series of ancestors of both sexes.

This subtle metaphysical conception is so foreign to the methods and tendencies of modern thought, that when we compare it with Hunter's simple and definite statement that the natural history characteristics of any species of animal are to be found in those properties that are common to both sexes, there does not seem to be any room for choice. The view that each individual inherits all the characteristics of the species, and that the distinctive characteristics of the male are arrested in certain ones, while the distinctive features of the female remain latent in others, furnishes a simple and adequate explanation of the facts, and removes all necessity for the subtle, complex and unthinkable, compound personality hypothesis.

In this connection the interesting and practical question, what determines the sex of the embryo, can hardly fail to suggest itself to the reader. I have refrained from a discussion of this important point in the body of this work, as it has no direct bearing upon our argument and I have no solution to offer. As I have so far omitted all reference to the subject, I will take occasion now to call attention, in this connection, to the facts detailed on pp. 55–69. The reader will see that all female bees are born from fertilized eggs, and all male bees from unfertilized eggs; while the unfertilized eggs of daphnia give rise to females only, and in many of the gall wasps both males and females are born from parthonogenetic eggs. There is no necessary or constant connection between the fertilization of the egg and the sex of the embryo, and the conclusion which I have reached from the study of these cases and of our scanty information upon the subject from other sources, is that sex is not determined by any constant law; that in certain animals and plants the sex of the embryo is determined by certain conditions, while in other groups it is determined by quite different conditions.

However this may be, it is obvious that since perfect males and perfect females may arise from eggs which are fertilized, and also from eggs which are not fertilized, the necessity for fertilization does not come from the necessity for transmitting to the offspring the organization of each parent.

A review of the opinions and reasoning of various authors shows that there is no good ground for believing that the two reproductive elements play similar parts in heredity and transmit every characteristic of each parent. It is impossible to prove it by the phenomena of crossing, since the only animals which can be made to cross are essentially alike, and differ only in minor points. The homology between the ovum and the male cell is no reason for supposing that their functions are similar. There is no reason for assuming that each sex transmits its entire organization to the offspring, since the latent transmission of secondary sexual characters can be more simply explained by assuming that each embryo inherits, but does not necessarily develop, all the characteristics of its species.

Reversion and alternation of generations admit of a similar explanation, and we may conclude that there is and can be no proof that each sexual element transmits all the characteristics of the parent. There is therefore no *a priori* absurdity in the hypothesis that the ovum and the male cell fill different offices. While there is no reason for believing that the functions of these elements are alike, there are many reasons for believing that this is not the case; for example, the almost universal occurrence of differences in form, size, and structure; the possibility of parthenogenesis; the differences between reciprocal hybrids; the fact that the offspring of a male hybrid and a female of a pure species is much more variable than the offspring of a female hybrid by the male of a pure species; and the fact that a part which is more developed or is of more functional importance in the male parent than it is in the female parent, is much more apt to vary in the offspring than a part which is more developed or more important in the mother than it is in the father.

In the absence of all evidence to the contrary I think we may safely conclude from this positive evidence that a division of physiological labor has arisen during the evolution of life, and that the functions of the reproductive elements have became specialized in divergent directions.

The only way to discover the exact nature of this specialization is to study the influence of each element separately, and the comparison of sexual with asexual reproduction is the best available method of doing this, since asexual reproduction is essentially reproduction without a male element, while sexual reproduction is reproduction with a male element.

Organisms produced from fertilized ova differ from those produced asexually only in their greater tendency to vary, and the hypothesis that the male element has become specialized *for the transmission of a tendency to vary* naturally suggests itself. Variation is not dependent upon fertilization, for plants produced from buds vary as well as those born from fertilized seeds, although bud variations are extremely rare as compared with seedling variations.

In any attempt to frame an hypothesis of heredity we must therefore recognize all the following facts: that the two reproductive elements are homologous, and that their functions were originally alike; that the possibility of parthenogenesis, together with many other well ascertained facts, shows that their functions are not alike, in the higher organisms, at present; that their present functions are due to divergent specialization or physiological division of labor; that variation is possible without sexual union, but that the introduction of a male element in reproduction greatly increases the frequency of its occurrence.

Among the unicellular organisms variability is provided for by conjugation, or the fusion of two entire individuals so that the new generation is derived from a compound germ which contains particles to represent all the parts of the body of each parent. In the metazoa and the many celled plants the reproductive bodies are localized and they are single cells, and there must therefore be some mechanism or organization in virtue of which they represent cells from all parts of the body, and thus provide for further variation.

These various considerations have led us to believe that each cell of the organism inherits from its unicellular ancestors the power to throw off cell germs or gemmules; that these germs penetrate to all parts of the body, and that those which thus reach the developing reproductive elements insure variation, in the next generation, in the cells which they represent; that originally the two sexual elements were alike in function; that each inherited from the fertilized ovum of the preceding generation the power to give rise to a new organism with all the established hereditary characteristics of the race; and that each element also had, by virtue of its contained gemmules, the power to transmit variability.

The existence, in each element, of the power to transmit the hereditary characteristics of the species is obviously superfluous, since the object of sexual union, the transmission of a tendency to vary, would be equally well secured if only one element had the power to transmit the common characteristics of both parents. I therefore believe that, as organisms gradually increased in size, as the number of cells in their bodies grew greater, and as the differentiation and specialization of these cells became more and more marked, one element, the male cell, became adapted for storing up gemmules, and, at the same time, gradually lost its unnecessary and useless power to transmit hereditary characteristics. This process was gradual, and even in the highest animals the power of the male cell to transmit hereditary characters does not seem to be completely lost, although few traces of it remain.

I also suppose that natural selection has acted upon the various cells of the body to restrain them from throwing off unnecessary gemmules, and that this power is exercised only when a change in the surrounding world renders variation necessary.

After framing this hypothesis the next step is to test it by applying it to the various observed phenomena of heredity in order to see how far it explains and interprets them. I have attempted to do this in chapters VI. to X. of this book, and I think we are justified in concluding, as the result of this review, that, while there are many facts which the hypothesis does not explain, they are not of such a character as to directly contradict it, while it does group and illuminate many classes of facts which are quite inexplicable without it.

The evidence from hybrids seems to be strongly in its favor, and it presents many features which are perfectly simple and natural, according to our view of heredity, although no other explanation of them has ever been offered.

Hybrids and mongrels are highly variable, as we should expect from the fact that many of the cells of their bodies must be placed under unnatural conditions, and must therefore have a tendency to throw off gemmules. Darwin's pangenesis hypothesis accounts for the variability of hybrids, but it does not account for the very remarkable fact that hybrids from forms which have long been cultivated or domesticated are more variable than those from wild species or varieties, or for the fact that the children of hybrids are more variable than the hybrids themselves.

Our view not only explains the variability of hybrids, but it also accounts for the excessive variability of hybrids from domesticated forms, and of the children of hybrids, for domesticated animals and plants live under unnatural conditions, and they are therefore more prolific of gemmules than wild species, and as the body of a male hybrid is a new thing the cells will be much more likely than those of the pure parent to throw off gemmules.

The fact that variation is due to the male influence, and that the action upon the male parent of unnatural or changed conditions results in the variability of the child, is well shown by crossing the hybrid with the pure species, for when the male hybrid is crossed with a pure female the children are much more variable than those born from a hybrid mother by a pure father.

The remarkable history of reciprocal crosses is, on the whole, exactly what we should expect, and although there are many difficulties, they are no greater than the complexity of the subject would lead us to anticipate.

The study of variation brings out a number of secondary laws, all of which might have been derived from our view of the nature of heredity.

The law that sexual offspring are more variable than those produced asexually has just been discussed, and it is clearly in perfect accordance with our view.

Another most interesting and remarkable law—that changed conditions do not act directly, but that they cause subsequent generations to vary—receives a simple explanation as soon as we recognize that variation is due to the transmission of gemmules, not to the direct modifying influence of external conditions.

We can also understand why variation should itself be hereditary, why specific characters should be more variable than generic characters, why species of large genera should vary more than species of small genera, why a part developed to an unusual degree or in an unusual way should also be extremely variable, and why secondary sexual characters should show a marked tendency to vary.

The study of secondary sexual characters aids us, like the study of hybrids and of variation, to analyze or disentangle the influences of the two sexes in heredity. These characters, therefore, possess especial interest in connection with our subject. They are found, upon examination, to present many striking peculiarities which might have been directly deduced from our view of the nature of heredity.

As gemmules which are formed in the male body are much more likely to be transmitted to descendants, and thus to give rise to variation, than gemmules which are formed in the female body, we should expect to find, in a variation which first appears in a male, much more tendency to become hereditary than in a variation which first appears in a female. For the same reason we should expect to find an organ which is confined to males much more likely than one confined to females to give rise to hereditary modifications.

For a similar reason we should expect the males of unisexual animals to vary more than the females.

We can form some conception of the amount of modification which an animal has recently undergone by comparing the adults with the young, and by comparing allied species with each other.

When we make comparisons of this kind we find that throughout the animal kingdom, with very few exceptions, wherever the sexes are separate and differ from each other, *the males of allied species differ from each* other more than the females do, and the adult male differs more than the adult female from the young. This law is so pronounced and conspicuous that its existence has long been recognized by all naturalists.

We also find that organs which are confined to males, or which are of more importance or are more perfectly developed in the males than they are in the females, are very much more likely to give rise to hereditary modifications than parts which are confined to or are most *developed in females; that a part which is thus confined* to males is much more likely to vary than a similar female part; that males are, as a rule, more variable than females; and that the male leads and the female follows in the evolution of new races.

The scientific accuracy of most of these generalizations regarding secondary sexual characters has long been recognized, although no one, so far as I know, has attempted to trace them back to a fundamental law of heredity. On the contrary, most of the authors who have discussed them have treated them rather as special cases than as the results of a general principle, and analysis shows that none of the explanations which have been advanced are sufficiently broad to cover the whole ground.

Daines Barrington and Wallace have held that the explanation of the fact that male birds and male insects are often so much more brilliantly colored and conspicuously ornamented than the females is to be found in the fact that the female, while laying her eggs or while incubating, is much more exposed to the attacks of enemies than the male, and that inasmuch as the perpetuation of the race depends upon the safety of the females at this time, natural selection has gradually exterminated the conspicuous females, and has preserved those with the least striking colors.

We know, however, that the male is usually more brilliantly colored than the female among reptiles which do not incubate, and even among certain fishes where the male attends to the eggs and young. It is therefore clear that Wallace's explanation stops short of the whole truth, and Darwin's exhaustive review of the subject seems to prove that among birds it is the male and not the female which has been directly modified.

Darwin believes that the greater modification of the males as compared with the females is due to sexual selection. The males have struggled with each other for the possession of the females, or have been selected by the females, and this process long continued is believed by him to have resulted in the perpetuation of the strongest, best armed, or most attractive males.

It is plain that sexual selection must have the effect which Darwin attributes to it, but the fact that even in choice breeds of domesticated animals which are mated according to the wishes of the breeder, and not according to their own selection, the males are more modified than the females, shows that behind the action of sexual selection some more profound law must exist.

Darwin believes that this explanation is to be found in the fact that the male usually has stronger passions than the female, and is consequently more exposed to the action of natural selection. He says that the perpetuation of the race depends upon the existence of the sexual passion, and that, since the male must in most cases seek the female, the most eager males have left the greatest number of offspring, and have thus become selected.

When we bear in mind the fact that the parental instinct is fully as important to the race as the sexual instinct, and that this is usually most developed in the female, we see that the failure of the female to undergo modification for the good of the species as frequently as the male cannot be explained without the recognition of some more general law. The singular history of secondary sexual characters receives a ready explanation by the law of heredity, for this law leads us to look to the cells of the male body for the origin of most of the variations through which the species has attained to its present organization.

Since gemmules which originate in a male body are more likely to be transmitted than those formed in a female body, and since gemmules are most likely to be formed in the sex in which an organ is of most functional importance, and therefore most subject to disturbing influences, we can readily see why a part which is important to males should vary more than a part which is important to females.

We are thus able to understand the great difference in the males of allied species, the difference between the adult male and the female or young, and the great diversity and variability of secondary male characters, and we should expect to find, what actually is the case, that among the higher animals, when the sexes have long been separated, the males are more variable than the females.

In the chapter on the intellectual differences between men and women, I have shown that those philosophical writers who have devoted especial attention to the subject have reached conclusions which are exactly what our hypothesis would lead us to expect. The view that the male mind is the progressive element in intellectual development, and the female mind the conservative element, accords with the views which have been generally recognized and accepted by the common consent of mankind, and although our opinions upon this very complicated subject may possibly be very far from accurate, a certain conformation to the demands of our hypothesis cannot be denied.

The facts relating to hybrids, to variation, to the secondary sexual characters of animals, and to the intellectual differences between men and women, which are stated at some length in chapters V. to IX., cover a very wide and diversified field, and any law which groups and explains them all is certainly worthy of careful examination. The most candid review which I am able to give to the evidence from all these sources, convinces me that the explanation which I have offered in this book is at least a step in the right direction, and that whether it be accepted in its present form or not, it does serve to enlarge our insight into the hidden relations between the phenomena of nature.

Chapter XI. is devoted to an examination of the law of natural selection, as modified by the law of heredity, and I have here attempted to show that the acceptance of this secondary law will remove the most serious objections to the view that our present forms of life have been brought into existence through the survival of the fittest variations, and I have also called attention to the fact that the law of heredity is itself a result of the law of natural selection.

No one can deny that there are grave objections to the law of natural selection in its original form. Darwin admits this in many places, and able but dissenting critics have stated most of these objections with great ability. The evidence for the law of natural selection is so many sided, so extensive, and so satisfactory, that we may fairly conclude that the difficulties will disappear with greater knowledge, and as none of its hostile critics have proposed anything whatever to take its place, the difficulties which they have pointed out have hardly received from naturalists the attention which they deserve.

One of the most serious objections is that natural selection cannot effect any permanent modification of a race, unless great numbers of individuals vary in essentially the same way at nearly the same time, and that the chances against this are great beyond computation if variations are purely fortuitous in Darwin's sense of the word.

Darwin has acknowledged the weight of this objection, and there is no escape from the conclusion that natural selection fails to account for the origin of species, unless we can show that many individuals tend to vary at the same time. According to our view, the production of gemmules and the consequent variations are due to the direct action of changed conditions upon certain cells of the body, and any change which affects all the individuals of a species will cause the same part to vary in all of them at the same time. This objection to the law of natural selection is thus entirely removed.

The evolution of a complicated organism, or the modification of any part which includes a number of complicated structures, without destroying their harmonious adjustment to each other, demands a very great number of variations, and if these are fortuitous, we may well doubt whether there has been time enough for the evolution of life by natural selection. According to our theory of heredity, a change in one part of the body is in itself a cause of variation in related parts; and as changes thus tend to occur where and when they are needed, the time which is demanded for the evolution of a complicated organ by natural selection is brought within reasonable limits, and one of the most fundamental objections is thus completely removed.

There are many reasons for believing that variations under nature may not be so minute as Darwin supposes, but that evolution may take place by jumps or saltations. According to our view a change in one part will disturb the harmony of related parts, and will cause their cells to throw off gemmules. A slight change in one generation may thus become in following generations a very considerable modification, and there is no reason why natural selection should not be occasionally presented with great and important saltations.

The law of heredity also enables us to understand the occasional occurrence of parallel or analogous variation, and the parallel evolution of polyphyletic-groups.