HEREDITY.

CHAPTER I.

WHAT IS HEREDITY?

The development of an animal, with the complex and beautiful structural adjustments, the instincts, habits, and individual traits of its parents is one of the most wonderful phenomena of the material universe—Heredity is not due to the external conditions which act upon the ovum, but to something within the ovum itself—The phenomena of reversion—Asexual and sexual heredity—Possibility of an explanation of heredity—Characteristics which are now hereditary were at one time new variations—Heredity and variation are opposite aspects of the same problem—We may hope that a more perfect acquaintance with the laws of heredity will remove many objections to the theory of natural selection.

To the ordinary unscientific reader the word heredity may perhaps suggest nothing more than a few curious cases where an odd peculiarity of the parent has been transmitted to the children, or it may recall the hereditary transmission of a tendency to certain diseases, or the mental or moral idiosyncrasies of the parents.

To the breeder of domestic animals or plants it has a somewhat wider significance, and recalls the transmission by choice or fancy breeds of the features which give them their value. To him heredity is the law which enables him to modify his animals and to build up and perpetuate new varieties.

To the naturalist, on the contrary, the word is filled with deep meaning, and instead of recalling to his mind a few odd cases, the tricks and accidents of heredity, it brings before him the most marvellous of all the phenomena of the material universe: the production from a simple egg of a living animal, with the intricate structure and complex bodily and mental functions of its proper species.

Thoughtful men in all ages have regarded the structure and faculties of the higher animals as a proper field for life-long study. Yet the acute intellects, the powers of patient observation and profound reflection which generations of naturalists have brought to this fascinating subject, have not yet given us a complete knowledge of the life of a single animal.

In every age and country where science has flourished men have devoted their lives to this subject, and have felt that their hardly-earned results could scarcely be called a beginning. So vast is the field, so many are the phenomena, that the province of natural science is practically infinite, for each animal and each plant presents special problems which open out in all directions before the student in an endless vista.

Wonderful and various as the attributes of each animal are, however, they are not mysterious; for, at the same time that we discover in an organism the power to do wonderful things, we also find in it a material organization, a mechanism, adopted to do these very things. It is true that we cannot perfectly understand this mechanism, that in many cases we fail completely in our attempts to trace its working, and that in most cases our insight is very crude indeed. Still we are able to show that the machinery exists; and anatomy, or the study of structure, goes hand in hand with the study of the bodily

and mental activities of animals. We do not understand the machinery, but we find that it is there, and we can interrupt its work by obstructing or injuring it. Our wonder is not a feeling of mystery, a sense that the phenomena transcend knowledge ; it is due to a perception of the amount of knowledge required. We regard an adult animal with feelings similar to those with which an intelligent savage might regard a telephone or a steamboat.

A dog, with all the powers and faculties which enable him to fill his place as man's companion, is a wonder almost beyond our powers of expression; but we find in his body the machinery of muscles and veins, digestive, respiratory, and circulatory organs, eyes, ears, etc., which adapts him to his place; and study has taught us enough about the action of this machinery to assure us that greater knowledge would show us, in the structure of the dog, an explanation of all that fits the dog for his life; an explanation as satisfactory as that which a savage might reach, in the case of the steamboat, by studying its anatomy.

Let our savage find, however, while studying an iron steamboat that small masses of iron, without structure, so far as the means at his command allow him to examine and decide, are from time to time broken off and thrown overboard, and that each of these contains in itself the power to build up all the machinery and appliances of a perfect steamboat. The wonderful thing now is not the adaptation of wonderful machinery to produce wonderful results, but the production of wonderful results without any discoverable mechanism; and this is, in outline, the problem which is brought before the mind of the naturalist by the word heredity.

Every one knows that each dog exists at some time

as an egg, and the microscope shows in this egg no traces of the organs of the dog's body or of anything at all like them. So far as our means of examination go the egg is no more like a dog than the mass of iron is like a steamboat. It may be said, though, that the dog's egg is not left to itself, but is fertilized and is carried inside the body of the mother until the new animal is matured; that it is there nourished and built up from substances supplied through the body of a full-grown dog; that it may be acted upon at this time by agencies which have a direct tendency to build up out of it an organism like the parent; that the egg does not actually contain a potential dog, but simply supplies the proper material to be acted upon by the surrounding conditions, and that the structure of the new animal is due to these conditions; that the embryo becomes a dog because it is bathed by a dog's blood, nourished through a dog's body, and is completely surrounded by influences which are peculiar to dog nature. Those persons who are not naturalists derive their knowledge of the animal world chiefly from our common domestic animals, and to such persons this explanation may seem probable; but naturalists, with wider experience, know that animals which carry their young inside their bodies are exceptions, and that the organization of the future animal must exist potentially in the egg, since the conditions to which it is exposed cannot possibly have any tendency to produce from it a being which does not already exist, in some form, within it.

A bee is almost as wonderful as a dog; its anatomical structure is exquisitely delicate and complex, and every one is acquainted with the wonderful work which it accomplishes. At the time it is laid the egg which is to become a worker-bee contains no visible trace of its

body, or of anything like it. It has been carefully studied with all the resources of modern science, but examination shows nothing within it which is more like a bee than a mass of iron is like an iron ship. This egg is not even fertilized, but it develops into a perfect worker, with all its wonderful structure and instincts, by virtue of something which it contained when it left the ovary of its mother. It is true that it is not left quite to itself, but is carefully attended and cared for by other bees; but everything which they do for it might be done just as well by delicate machinery, and the attention has no tendency whatever to manufacture a bee. Proper heat and access to air are as necessary as attention, and attention has no more power to produce a bee than air or heat.

No one who is familiar with marine animals can believe for an instant that the conditions to which an egg is exposed have anything whatever to do with the character of the animal to which it gives rise. We may artificially remove eggs from the ovaries of several different animals, fertilize them artificially, and then place them together in a tumbler of sea water, and expose them to exactly similar external conditions, yet each one will follow its own determined course, and we may rear in the same tumbler of water from eggs which are hardly distinguishable animals which have less in common than a dog and a bird.

If there is no mystery in the performance by the complicated organs of an adult animal of all its complicated functions, what shall we say when we find the power to perform these functions existing in a latent state in the egg, without the corresponding organs?

This is the problem of heredity. In the mind of the naturalist the word calls up the greatest of all the wonders of the material universe: the existence, in a simple,

unorganized egg, of a power to produce a definite adult animal, with all its characteristics, even down to the slightest accidental peculiarity of its parents; a power to reproduce in it all their habits and instincts, and even the slightest trick of speech or action.

This is by no means the whole of the problem of heredity. One of the most interesting phenomena connected with our subject is what is known as reversion, or the appearance in the child of peculiarities which were not present in either parent, but are due to inheritance from a grandparent or a more remote ancestor. An interesting illustration of this law is the occasional appearance in horses of stripes on the body and legs. Such stripes are not usually present in the horse, although Darwin has given reasons for believing that our horses are descended from a striped zebra-like ancestor. The power to revert to this ancestral form is handed down from generation to generation in the egg, and it may show itself at any time by the production of a striped colt. Reversion is, in a certain sense, exceptional, but it is not at all rare, and we must add this power to the wonderful properties of the egg.

Darwin gives the following case, which will serve to illustrate the nature of reversion: A pointer bitch produced some puppies; four were marked with blue and white, which is so unusual a color in pointers that she was thought to have played false with one of the greyhounds, and the whole litter was condemned, but the gamekeeper was permitted to save one as a curiosity. Two years afterwards a friend of the owner saw the young dog, and declared that he was the image of his old pointer bitch, Sappho, the only blue and white pointer of pure descent which he had ever seen. This led to close inquiry, and it was proved that he was the great-

great-grandson of Sappho; so that, according to the common expression, he had only one-sixteenth of her blood in his veins.

Another aspect of our subject must be kept constantly in mind. Among the higher animals heredity usually manifests itself only by what is known as sexual reproduction,—that is, the development of new individuals from fertilized eggs; but in the lower forms of life another kind of reproduction, the development of new individuals by budding or by analogous processes, is even more common. Among the hydroids heredity may manifest itself by the formation of new animals, with all the characteristics of the parent, on almost any part of the body of the latter, and in certain plants the smallest fragment of tissue may become a new and perfect plant, capable of producing others in the same way or by seeds. The most sure and rapid way to get new sea-anemones is to tear an old one to pieces. As a rule this power is confined to the lower forms of life, but certain animals which are by no means low or simple in structure multiply asexually, and the offspring thus produced inherit, like those developed from eggs, all the characteristics of the parent.

This then is the problem of heredity, certainly one of the grandest secrets of nature. When we reflect upon its obscurity and complexity we may fairly ask what hope there is of discovering its solution; of reaching its true meaning, its hidden laws and causes. If it is true that, in each egg, all the functions and faculties of a definite mature animal lie hidden, without any corresponding organs, must we not regard heredity as a mystery too great for solution; as something which must be accepted as it is without scientific explanation?

Thirty years ago the adaptation of each organ of an

adult animal to its proper purpose seemed to be a mystery of the same kind, and many profound thinkers satisfied themselves and taught others that this adaptation was not brought about by the laws of matter and by secondary causes; that it must be accepted in itself, without explanation, and that the methods of physical science are here of no use.

Darwin's work has taught us that this is not true; that in the law of natural selection we have at least a partial explanation of the origin of the adaptations of nature; that while natural selection may not be the exclusive means by which they have been produced, it is, so far as it goes, a true scientific explanation, for it even puts it in our power to produce, in domestic animals, similar adaptations to special purposes, by the selection of the fittest variations.

Darwin, in his first and in all his later books on the subject, pointed out that his discovery did not complete the solution of the problem; that "natural selection is a great but not the exclusive means of modification." The greatest value of his work lies in the proof which he has furnished, that the origin of the structure of animals is not beyond our reach, but that observation and reflection, the means which have unlocked for us so many of the secrets of inorganic nature, are equally useful in this field; that the adaptations of nature may be studied and understood like a problem in astronomy or physics.

The aim of this work is to show that the same thing is true of the problem of heredity.

We may not be able, as yet, to penetrate its secrets to their inmost depths, but I hope to show that observation and reflection do enable us to discover some of the laws upon which heredity depends, and do furnish us with at

least a partial solution of the problem; that we have every reason to hope that in time its hidden causes will all be made clear, and that its only mystery is that which it shares with all the phenomena of the universe.

In this introductory statement we have presented one side of the problem of heredity: the transmission from parent to child of the established congenital hereditary characteristics of the race. We must not forget, though, that there is another aspect which is fully equal to this in importance. We know that each characteristic has been gradually acquired through a long series of modifications; that all the wonderful adaptations which fit animals to their surroundings, and meet their particular needs, have been evolved step by step by the natural selection of the fittest congenital variations. Each race-characteristic has at one time been a new variation, and the process of modification is still going on and perfecting the harmony between the structure of each organism and its needs. No theory of heredity has any value unless it explains the way in which new features, which may become hereditary, continually make their appearance as congenital variations, at the same time that it accounts for the way in which established peculiarities are handed down from generation to generation.

The problem is two-sided; what is now hereditary was at one time variation, and each new variation may soon be hereditary. Heredity and variation are opposite aspects of the same thing, and an explanation must be examined and tested on the one side, as well as on the other, before it can be accepted.

There is still another consideration which remains to be noticed.

Darwin has never failed to perceive, and he has frequently pointed out, that the law of natural selection is not

a complete explanation of the origin of species, and that it is exposed to certain very serious difficulties.

Still he concludes that the theory is supported by such a mass of evidence that we may fairly believe that our own knowledge, not natural selection, is at fault, and that further research will remove the difficulties by the discovery of other laws.

Naturalists all over the world have acknowledged the justice of this claim, and some, less candid and broad-minded than Darwin, seem to have even lost sight of the difficulties.

Now natural selection can act only by the preservation of such variations as chance to appear, and until we know the laws which govern the appearance of variations it must be impossible to decide how far the course of organic evolution has been determined by these unknown laws, and how far by natural selection.

We may therefore entertain a reasonable hope, that when the true theory of heredity is discovered, it will, by revealing to us the laws and causes of variation, place the law of natural selection upon a firmer basis, and show that its apparent difficulties are simply due to the narrow limits of our knowledge.

With this introduction I will pass to the discussion of our subject, the nature of heredity.

The attempt to generalize from the whole field of natural science is beset with many difficulties, since the field is so vast that an attempt to give in advance a statement of all the facts upon which reasoning is based would simply confuse the mind of the reader, and burden him with a mass of detail.

It seems best then to start with the generalizations which are believed to bind the facts together, so that the reader may then approach the specific proofs with more

interest. The latter method is open to objection, since the reader may be called upon to listen to views which are opposed by accepted authorities, and to wait until the proofs are presented in due course.

I must therefore request the reader to suspend judgment, and to lay aside established opinions, until he has examined the subject upon all sides.

The examination of the history of the subject will furnish an introduction to its scientific discussion, and I have therefore adopted the following plan:

I shall give, first, an outline of the chief hypotheses which have been proposed, from time to time, as an explanation of heredity, with reasons for rejecting them. I shall then present briefly, in outline, a statement of what I believe to be the true explanation. I shall then try to show that this theory furnishes a basis or foundation for the theory of natural selection, and removes the most serious difficulties which have been urged against the latter theory. I shall then show that there is no *a priori* reason for rejecting the theory of heredity; and that it furnishes an explanation of many well-known facts which cannot without it be seen in their true relations. I shall then attempt to show that it is supported by direct proof, and finally I shall give a statement of the theory in a more extended form.