HEREDITY

CHAPTER I

HEREDITY AND INHERITANCE: DEFINED AND ILLUSTRATED

"Heredity is a sort of maze in which science loses itself."—BALZAC.

§ 1. *Importance of the Study of Heredity*

Heredity determines the Individual Life.—There are no scientific problems of greater human interest than those of Heredity—that is to say, the genetic relation between successive generations. Since the issues of the individual life are in great part determined by what the living creature is or has to start with, in virtue of its hereditary relation to parents and ancestors, we cannot disregard the facts of heredity in our interpretation of the past, our conduct in the present, or our forecasting of the future. Great importance undoubtedly attaches to Environ-

ment in the widest sense,—food, climate, housing, scenery, and the animate *milieu*; and to Function in the widest sense,—exercise, education, occupation, or the lack of these; but all these potent influences act upon an organism whose fundamental nature is determined, though not rigidly fixed, by its Heredity—*that is, we repeat, by its genetic relation to its forebears.* As Herbert Spencer said, "Inherited constitution must ever be the chief factor in determining character"; as Disraeli said, more epigrammatically and less correctly, "Race is everything."

Heredity is a Condition of all Organic Evolution.—In the same way, when we consider the race rather than the individual, we must admit that in so far as evolution depends on inborn organic changes, on what is bred in the bone and imbued in the blood, as distinguished from individual efforts and acquirements, external institutions and traditional culture, it is conditioned by the hereditary relation which binds one generation to another. Heredity is a *condition* of all organic evolution. Innate changes or variations, which form the raw material of constitutional progress or degeneracy, have direct racial importance because they are certainly transmissible; while, on the other hand, bodily modifications or acquired characters, due to changes in environment or in function, probably have no *direct* racial importance, since there is little or no evidence that they are ever hereditarily entailed. They are individually important, and in human society they are of much moment, but if they are not transmissible they do not take organic grip, and they cannot afford material for selection to work with. For the human race, the external heritage of tradition, institutions, and law, the permanent products of literature and art, the registrated results of science, and so on, are of paramount importance, but they are outside the immediate problem of organic or natural inheritance. As far as the slow, sure process of constitutional or organic evolution is concerned, everything depends on the heritable resemblances and the heritable variations which form

the material on which the many diverse forms of selection and isolation operate.

In olden days thoughtful men seemed to see the threads of life within the hands of three sister Fates,—of one who held the distaff, of another who offered flowers, and of a third who bore the abhorred shears of death. So, in Scandinavia, the young child was visited by three sister Norns, who brought characteristic gifts of the past, the present, and the future, which ruled the life to be as surely as did the hands of the three Fates. So, too, in days of scientific enlightenment, we still think of Fates and Norns, though our conceptions and terms are very different. What the living creature is or has to start with in virtue of its hereditary relation; what it does in the course of its activity; what surrounding influences play upon it,—these are the three determining factors of life. Heredity, function, and environment—*famille, travail, lieu*—are the three sides of the biological prism, by which, scientifically, we seek to analyse the light of life, never forgetting that there may be other components which we cannot deal with scientifically, just as there are rays of light which our eyes can never see.

In novels like Zola's *Dr. Pascal*, in plays like Ibsen's *Ghosts*, in sermons and newspaper articles, in large books and health lectures, in season and out of season, we have all heard in the last few years much about the importance of heredity; and though it is to be feared that many widespread impressions on the subject are misleading, the awakening of keen interest is in itself a symptom of progress. What is now required is a serious study of what has been securely established. Otherwise we shall continue to think in platitudes and act on guesses.

Practical Importance to Breeders and Cultivators.—And what is important in regard to Man's heredity is even more demonstrably important in regard to his domesticated animals and cultivated plants. What has been achieved in the past in regard to horses and cattle, pigeons and poultry, cereals and

chrysanthemums, by experimental cleverness and infinite patience, may be surpassed in the future if breeders and cultivators can attain to a better understanding of the more or less obscure laws of inheritance on which all their results depend.

Importance in Biological Theory.—The study of heredity is also of fundamental importance in the domain of pure science, in the biologist's attempt to interpret the process of evolution by which the complexities of our present-day fauna and flora have gradually arisen from simpler antecedents. For heredity is obviously one of the *conditions* of evolution,—of continuance as well as of progress. There would have been heredity even if there had been a monotonous world of Protists without any evolution at all, but there could not have been any evolution in the animate world without heredity as one of its conditions. The study of heredity is inextricably bound up with the problems of development, reproduction, fertilisation, variation, and so on; in short, it is one of the central themes of Biology.

§ 2. *What the Terms Mean*

The Terms are tinged with Metaphor.—In the popular, if not also in the biological mind, there often lurks the idea of a hypothetical agent possessing the organism and uniting the congeries of its characters. Expressed in diverse ways, there is a prevalent conception of an organismal unity which gives coherence to the sum of qualities (see Sandeman, 1896). Especially in reference to higher animals with a rich mental life, many find it impossible not to think of a "soul" or "self" to which the body *belongs*. Naturally enough, therefore, the reappearance in the offspring of qualities which characterised its parents or its ancestors has been persistently likened to the inheritance of a legacy. But this is to some extent a metaphorical expression, and not without its dangers.

At first the Organism and the Inheritance are Identical.—A

moment's consideration suffices to show that ideas and phrases borrowed from the inheritance of property—something quite apart from the individual who inherits—are apt to cause obscurity and fallacy when applied to the inheritance of characters which literally constitute the organism and are inseparable from it. Therefore, as the biological conception of inheritance seems still to suffer from the irrelevancy of the analogy to which

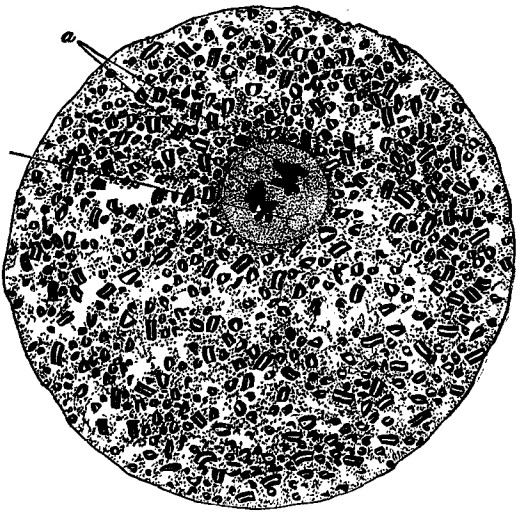

FIG. 1.—Ovum of a threadworm (*Ascaris*), showing (*a*) the chromosomes of the nucleus, and the reserve products in the surrounding cell-substance.—From Carnoy.

the term owes its origin, let us dwell for a little on the fact that, at the start of an individual life, the inheritance and the organism are identical. In other words, the idea of organic inheritance is merely a convenient scientific abstraction, by which we seek to distinguish what the organism is, in virtue of its germinal origin, from what it is as the result of the influence of ensuing circumstances. If we may use Galton's and Shakespeare's terms, the idea of organic inheritance is an abstraction by which

we seek to distinguish what is due to "Nature" from what is due to "Nurture."

Heredity and Inheritance defined.—In regard to property there is a clear distinction between the heir and the estate which he inherits, but at the beginning of an individual life we cannot biologically draw any such distinction. The organism and its inheritance are, *to begin with*, one and the same. It is easy to make this clear. Every living creature arises from a parent or from parents more or less like itself; this reproductive or genetic relation has a visible material basis in the germinal matter (usually egg-cell and sperm-cell) liberated from the parental body or bodies; by inheritance we mean all the qualities or characters which have their initial seat, their physical basis, in the fertilised egg-cell; the expression of this inheritance in development results in the organism. Thus, heredity is no entity, no force, no principle, but a convenient term for *the genetic relation between successive generations*, and inheritance includes *all that the organism is or has to start with in virtue of its hereditary relation.*

Nature and Nurture.—The fertilised egg-cell implicitly contains, in some way which we cannot image, the potentiality of a living creature,—a tree, a daisy, a horse, a man. If this rudiment is to be realised there must be an appropriate environment, supplying food and oxygen and liberating-stimuli of many kinds. Surrounding influences—maternal or external—begin to play upon the developing germ, and without these influences the inheritance could not be expressed, the potentialities could not be realised. Thus, the organic inheritance implies an environment, apart from which it means nothing and can achieve nothing. Indeed, it is only by an abstraction that we can separate any living creature from an environment in which it can live. Life implies persistent action and reaction between organism and environment.

But while the inherited nature and its possibilities of action

and reaction must be regarded as rigorously determined by the parental and ancestral contributions, the nurture—the environmental influences—must not be thought of as pre-determined. In fact, the surrounding influences are very variable, and the nature of the young organism may be profoundly changed by them. Thus, we soon find it possible to distinguish between the main features, which are the normal realisations of the inheritance in a normal environment, and peculiarities which are due to peculiarities in nurture. The characters of a newly-hatched chick stepping out of the imprisoning egg-shell are in the main strictly hereditary; but they need not be altogether so, for during the three weeks before hatching there has been some opportunity for peculiarities in the environment to leave their mark on the developing creature. Still more is this the case with the typical mammalian embryo, which develops often for many months as a sort of internal parasite within the mother—in a complex and variable environment. And as life goes on, peculiarities due to nurture continue to be superimposed on the hereditary qualities.

William of Occam's Razor.—Our preliminary attempt to get rid of capitals, to make the terms heredity and inheritance quite objective, is in line with what has occurred in other departments of science. For one of the distinctive features of the nineteenth century has been a reduction in the number of supposed separate powers or entities—the use of William of Occam's razor, in fact. "*Entia non sunt multiplicanda prœter necessitatem.*" "Caloric" was one of the first to be eliminated, yielding to the modern interpretation of heat "as a mode of motion"; "Light" had to follow, when the undulatory or the electro-magnetic theory of its nature was accepted; a specific "Vital Force" is disowned even by the Neo-vitalists; "Force" itself has become a mere measure of motion; and even "Matter" tends to be resolved into units of negative electricity, carrying with them a bound portion of the ether in which they are bathed; and so on. In

view of this progress towards greater precision and simplification of phraseology, it cannot be a matter for surprise that a biologist should affirm that to speak of the "Principle of Heredity" in organisms is like speaking of the "Principle of Horology" in clocks. The sooner we get rid of such verbiage the better for clear thinking, since heredity is certainly no power, or force, or principle, but a convenient term for the relation of organic or genetic continuity which binds generation to generation. Ancestors, grandparents, parents are real enough; children and children's children are also very real; heredity is a term for the relation of genetic continuity which binds them together. We study it as a relation of resemblances and differences which can be measured or weighed, or in some way computed; as a relation which is sustained by a more or less visible material basis —namely, the germinal matter

§ 3. *Heredity and Inheritance in Relation to other Biological Concepts*

Development.—All living creatures arise from parents more or less like themselves. The reproduction may be *asexual*,—by fission, fragmentation. budding, and similar processes; or *sexual*,—by special germ-cells or gametes, which usually unite in pairs (fertilisation or amphimixis) to start a new individual body. Whatever the *mode of reproduction* may be—and that is a long story by itself—there is a hereditary relation, a genetic continuity. It is the business of the *theory of heredity* to inquire into the precise nature of this genetic relation in the diverse modes of reproduction. In what relation, for instance, does a liberated germ-cell or gamete stand to the body which liberates it? In what relation does a fertilised ovum stand to the germ-cells of the body into which it develops? What contribution does each parent make to the inheritance? Do ancestors also make contributions, and if so, how? To answer this kind of question is the business of *the theory of heredity*.

The separated fragment or the liberated germ-cell has in it the possibility of becoming, in an appropriate environment, a fully-developed organism. Is it possible to form any conception —verifiable or speculative—of the manner in which the inheritance is thus condensed into a fragment or into a germ-cell? Is it possible to picture in any way how the potentialities come to be realised in development; how the obviously complex grows out of the apparently simple? To answer these and similar questions is the business of *the theory of development.*

The facts of *inheritance* are those which rise into prominence when we compare the characters of an organism with those of its parents and its offspring, or when we compare the characters of one generation with those of its predecessors and successors. This is a thoroughly concrete study, for the facts observed are quite independent of any theory of the precise organic relation which binds generation to generation (*the theory of heredity*), and are also quite independent of any theory as to the way in which the germ grows into the adult (*the theory of development*). It is, in the main, an observational and statistical study.

Before the middle of the nineteenth century considerable attention was given to what may be called the demonstration of the general fact of inheritance—that like tends to beget like. This had, indeed, always been the general opinion of physicians and naturalists, as well as of the laity, but it was a useful task to collect documentary evidence showing that all the inborn characteristics of an organism, whether physical or psychical, normal or abnormal, important or trivial, were *transmissible* to the offspring, if the possibility of having offspring had not been excluded. This task of demonstrating inheritance was well finished by Prosper Lucas, whose large treatise, published in 1847, gave ample evidence for what we now take for granted,—that the present is the child of the past; that our start in life is no haphazard affair, but is rigorously determined by our parentage and ancestry; that all kinds of inborn characteristics may

be transmitted from generation to generation. In short, the fundamental importance of inheritance was long ago demonstrated up to the hilt.

It remains, however, (1) to make the evidence of transmissibility more precise and systematic; (2) to inquire into the transmissibility of subtle characters such as longevity and fecundity; (3) to discover the different degrees of transmissibility, for some characters are much more heritable than others; and (4) to classify different modes of hereditary resemblance—*e.g.* blending of the characters of the two parents, taking after the father in one feature and after the mother in another, apparently resembling one parent only, rehabilitating a grandsire's features, harking back to a remoter ancestor, and so on. What happens when there is close in-breeding or pairing within a narrow radius of relationship? What happens when two hybrids are paired? In what sense, if any, is a disease heritable? These and many similar questions will be discussed in our inquiry into *the facts of inheritance.*

Variation.—Whenever we begin to compare the characters of an organism with those of its parents, we discover that the familiar saying, "Like begets like," must be modified into, "Like tends to beget like." On the one hand, the child is like its parents, "a chip of the old block," a literal *reproduction*; on the other hand, the child is something original, a new pattern, a fresh start—leading the race. We do not gather grapes of thorns, or figs of thistles; yet two brothers may be very unlike one another or either of their parents, and even the peas in one pod may be different. On the one hand, there is a tendency towards continuity, towards persistence of characters, towards complete hereditary resemblance—in short, a kind of organic inertia in a family or stock or species. On the other hand, there is a tendency towards variation, towards new departures, towards incomplete hereditary resemblance, or much more than that. It is necessary to hold the balance between these two

sets of facts, both expressions of the hereditary relation,—inertia, persistence, continuity, resemblances, on the one hand; deviation, novelty, differences, on the other.

Can we hope to discriminate an *apparent* difference between parent and offspring, which is really due to an incompleteness in the expression of the inheritance, from a *real* difference, which is due to the dropping out of an old hereditary item or the addition of a new one? Can we distinguish between inborn peculiarities—germinal variations—and acquired, nurtural peculiarities? Can we distinguish between variations which seem to be simply a little less or a little more of some hereditary character, and variations which involve something new? These and similar questions must be faced in *the study of variation.*

Modifications.—Furthermore, whenever the study of the facts of inheritance becomes critical, it is necessary to try to discriminate between inborn changes, which must have a germinal origin, and are therefore in the strict sense *inherited*, and are liable to be transmitted, and those theoretically quite different changes which are acquired by the body of the individual offspring as the result of peculiarities in function and environment. This is the contrast between *germinal variations* and *bodily modifications*, a contrast which is of fundamental importance in several ways. It is important to try to distinguish resemblances and differences due to inherited nature from resemblances and differences due to nurture. A collier may have his collier father's red hair, and he may also resemble him in having "collier's lung." But while the first resemblance is a fact of inheritance, the second is due to the similarity in their life-conditions. This distinction remains important whatever conclusion be reached in regard to the transmissibility of modifications, but its importance is enhanced when we discover that practically all variations (except sterility) are transmissible, though not always transmitted, and that the evidence of any modification

being transmissible, among multicellular organisms reproducing sexually, is extremely doubtful.

Evolution.—Briefly and concretely stated, the general doctrine of organic evolution suggests, as we all know, that the plants and animals now around us are the results of natural processes of growth and change working throughout unthinkably long ages; that the forms we see are the lineal descendants of ancestors on the whole somewhat simpler; that these are descended from yet simpler forms, and so on, backwards, till we lose our clue in the unknown, but doubtless momentous, vital events of pre-Cambrian ages, or, in other words, in the thick mist of life's beginnings. The essentially simple idea is that the present is the child of the past, and the parent of the future. It is a way of looking at organic history, a genetic description, a modal formulation. A process of Becoming leads to a new phase of Being; the study of evolution is a study of *Werden und Vergehen und Weiter-werden.*

But we have to pass from a modal interpretation to a causal one. We have to try to discover the factors in the age-long process, and this leads us into a region where at present uncertainties abound. As biologists we start with the postulate of simple living organisms—feeding, working, growing, wasting, reproducing in an appropriate environment. And we try to discover the possible factors in the long evolution-process, the outcome of which is the present-day world of life. Amid all the uncertainties, this is certain, that the fundamental condition of evolution is that genetic relation which we call heredity,—a relation such that it admits, on the one hand, of a continuity of hereditary resemblance from generation to generation; and, on the other hand, of an organic changefulness which we call variability. Without the hereditary relation there could have been no succession of generations at all. Without hereditary resemblance on the one hand, and hereditary variation on the other, there could have been no evolution. Any discussion of

the secondary or directive factors which operate upon the raw materials of progress which variability supplies—notably Selection and Isolation—is not relevant at present.

§ 4. *A Question of Words*

In every discussion with a serious purpose it is important that there should be clearness as to the terms used. We must, therefore, ask the reader to notice our definition of the chief terms. Thus by "heredity" we do not mean the general fact of observation that like tends to beget like, nor a power making for continuity or persistence of characters—to be opposed to the power of varying—nor anything but *the organic or genetic relation between successive generations*; and by "inheritance" we mean "organic inheritance"—*all that the organism is or has to start with in virtue of its hereditary relation to parents and ancestors.* We do not forget that for man in particular there is an external heritage—a social inheritance—which counts for much. By innate or inborn we mean all that is potentially implied in the fertilised egg-cell; by the expression of the inheritance we mean the realisation of inborn potentialities in the course of development in an appropriate environment; by a congenital character (*pace* many medical writers) we mean one demonstrable at birth, which is not necessarily germinal, being often due to peculiarities—*e.g.* infection or poisoning or mechanical injury during pre-natal development. Thus, tubercle may be congenital, but it is never inherited. By modifications or acquired characters we mean structural changes in the body induced by changes in the environment or in the function, and such that they transcend the limit of organic elasticity, and therefore persist after the inducing conditions have ceased to operate. By a variation we mean not *any* observed difference between offspring and parent, between an individual and the mean of

the stock in respect of a given character; we mean observed differences minus all bodily modifications, we mean changes which have a germinal origin.

These definitions will become clearer in the course of our exposition. Our present point is to warn the reader against starting on his journey without reading the conditions on the ticket, and to protest against the slackness with which the terms are so often used. A large part of the energy expended on the long-drawn-out controversy as to the transmission of acquired characters or modifications has been wasted through inattention to the precise significance of the technical terms employed.*

To speak of a man "fighting against his heredity" may express a real fact, but it is verbally erroneous. The American's question, "Is my grandfather's environment my heredity?" is an offence against ordinary English as well as against scientific phrasing; it should probably read, "Have the structural changes induced by environmental influences on my grandfather's body had any effect on my inheritance?" Nor can we pardon from an expert such a sentence as this, "I look upon Heredity as an acquired character, the same as form or colour, or sensation is, and not as an original endowment of matter" (Bailey, 1896, p. 23). When the moralist writes: "The only limitations imposed on a man are those which his own nature makes," the biologist asks, "But what is his own nature? Is

* It may be noted that Galton's work on *Natural Inheritance* is rightly so entitled, for it deals mainly with a statistical comparison of the characters of successive generations. Inheritance is also the chief subject of the works of Lucas and Ribot, although these have heredity for their title. Or, to take another example, Weismann's work entitled *The Germ-Plasm, a Theory of Heredity*, is in great part a theory of heredity, but, naturally enough, it is also in great part a theory of development. The German language has the same word, *Vererbung*, for both Heredity and Inheritance. As the English language is rich in related terms, laxity of expression is less excusable. Besides "heredity" and "inheritance" we have "heritage," "transmission," and so on. It may be convenient to speak of the parent as transmitting and of the offspring as inheriting.

it not the expression of a predetermined inheritance in a more or less predetermined environment ? "

Definitions of "Heredity."—It may be of interest to give a few samples of definitions :

" The word ' Heritage ' has a more limited meaning than ' Nature,' or the sum of inborn qualities. Heritage is confined to that which is inherited, while Nature also includes those individual variations that are due to other causes than heredity, and which act before birth."—Francis Galton, *Natural Inheritance*, 1898, p. 293.

" Heredity is the law which accounts for the change of type between parent and offspring, *i.e.* the progression from the racial towards the parental type."—Karl Pearson, *The Grammar of Science*, 1900, p. 474.

" Under heredity we understand the transference to the offspring of qualities of the parent or parents."—T. H. Montgomery, Jr., *Proc. American Phil. Soc.* xliii. 1904, p. 5. [But the line of descent is from germ-cell to germ-cell. The parent is the custodian or trustee of the germ-cells rather than their producer. It is too metaphorical to speak of the " parent transferring qualities to the offspring." The hereditary relation includes the occurrence of variations as well as the reproduction of likenesses. And what are the offspring apart from their inheritance ?]

" ' Heredity ' is most usually defined by biologists as referring generally to all phenomena covered by the aphorism ' like begets like.' In this sense it denotes, *inter alia*, the phenomenon of the constancy of specific or racial types and of sexual characters ; a character may be said to be *inherited* when it always, in one generation after another, is one of the characters of the species, of the race, or of the one sex of the race, as distinct from the other. The species, race, or sex, so to speak, ' begets its like ' as a whole. But then a further question remains ; even if the type of the race is constant, do *individual* types within the race beget their like ? In so far as any *individual* diverges in character from the mean of the race, do his offspring tend to diverge in the same direction, or not ? It is to this question that statisticians have confined themselves, and they speak of a character being ' inherited ' or not according as the answer to the question is yes or no—they deal solely with what we may term ' *individual* heredity.' "—G. Udney Yule, 1902, p. 196. [Biologists are as much concerned with individual

heredity as statisticians are, indeed more so; statistical results are based on individual data, but they do not admit of individual application.]

"Living matter has the special property of adding to its bulk by taking up the chemical elements which it requires and building up the food so taken as additional living matter. It further has the power of separating from itself minute particles or germs which feed and grow independently and thus multiply their kind. It is a fundamental character of this process of reproduction that the detached or pullulated germ inherits or carries with it from its parents the peculiarities of form and structure of its parent. This is the property known as Heredity. It is most essentially modified by another property—namely, that though eventually growing to be closely like the parent, the germ (especially when it is formed, as is usual, by the fusion of two germs from two separate parents) is never identical in all respects with the parent. It shows Variation. In virtue of Heredity, the new congenital variations shown by a new generation are transmitted to their offspring when in due time they pullulate or produce germs."—E. Ray Lankester, *Kingdom of Man*, 1907, p. 10.

"By inheritance we mean those methods and processes by which the constitution and characteristics of an animal or plant are handed on to its offspring, this transmission of characters being, of course, associated with the fact that the offspring is developed by the processes of growth out of a small fragment detached from the parent organism."—R. H. Lock, *Recent Progress in the Study of Variation, Heredity, and Evolution*, 1906, p. 1.

"Heredity.—The transference of similar characters from one generation of organisms to another, a process effected by means of the germ-cells or gametes."—Lock, *op. cit.* p. 292.

§ 5. *The Problems Illustrated*

Even in ancient times men pondered over the resemblances and differences between children and their parents, and wondered as to the nature of the bond which links generation to generation. But although the problems are old, the precise study of them is altogether modern. The foundations of embryology had to be laid, the nature and origin of the physical basis of inheritance

—the germ-cells—had to be elucidated, the general idea of evolution had to be realised, before the problems of heredity and inheritance could even be stated with precision. Moreover, it seems to have required the experience of many years of "fumbling" before the main body of biologists became convinced that the problems could not be satisfactorily studied in the armchair, nor settled by *a priori* argument. Now, however, it is unanimously agreed that a satisfactory study of heredity and inheritance demands a minute inquiry into the history of the germ-cells, a statistical study of the characters of successive generations, a careful criticism of the older data and of popular impressions, and a testing of hypotheses by experimental breeding. Let us give a few random illustrations in order to show what some of the problems are :

The race-horse Eclipse was the sire of many foals: it is a problem in heredity to compare them with him, and to inquire into the vital arrangements, in virtue of which many of them reproduced his remarkable quality of swiftness. He had also a peculiar, quite useless spot of colour, which reappeared even in the sixth generation of his progeny.

In the ancestry of Kaiser Wilhelm II. there have been four grandparents, eight great-grandparents, fourteen (not 16) great-great-grandparents, twenty-four (not 32) great-great-great-grandparents : it is a problem in heredity to compare the qualities of these successive generations of ancestors, and to inquire if they render more intelligible the illustrious personality whose doings and sayings are familiar to us all.

The assassin of the Empress of Austria is said to have been the child of a dissolute mother and a dipsomaniac father : it is a problem in heredity to inquire whether this parentage may render more intelligible an outrage which made Europe shudder.

A white man of considerable intellectual ability marries a negro woman of great physical beauty and strength ; the result may be—has been—a mulatto who inherits some of his father's

intellectual virtue and some of his mother's physical strength, including, for instance, a peculiar insusceptibility to yellow fever. Here are complex problems of inheritance. How is it that certain characteristics of the son are almost wholly of paternal origin, while in other respects he takes after his mother ?

An English sheep-dog may show a paternal eye on one side of the head, a maternal eye on the other. A piebald foal may have its mother's hair on some patches, its father's hair on others. Such cases raise the problem of the different modes of hereditary resemblance, of the mosaic-like constitution of an inheritance, and of the various ways in which this may find expression in development.

De Vries (1903) tells us of a well-known shrub of the hybrid Adam's laburnum (*Cytisus adami*), which grew in the village of Bloemendael, in Holland. This hybrid is a cross between the common laburnum (*Cytisus laburnum*) and another species of the same genus, *Cytisus purpureus*, and has some traits of both. It is, however, absolutely sterile, and is multiplied by grafts. The tree in the village was particularly interesting, for it bore three kinds of flowers,—some pink, others large and yellow, others small and purple. That is to say, it bore its own hybrid flowers, and also those of its two parents, and the leaves and ramifications of the parts of the tree which bore these three kinds of flowers were likewise of the same three kinds, and could be distinguished even in winter. In other words, in the same organism there were three kinds of characters, which could be separated out from one another in the course of growth. The characters of the two parents may combine in a close companionship, but when certain conditions arise the companion-characters may separate and each set may pursue its own path. It is an intricate problem to study the relation of a hybrid's characters to those of its parents.

In Chapter X. we shall have to allude to many problems like the following :

A pair of blue Andalusian fowls of selected breed have chickens. But only about half of these are "blue," the rest are blacks or splashed whites. Why is this? The blacks inbred produce only blacks, the splashed whites produce splashed whites or whites, but if the blacks and splashed whites are paired the progeny is altogether "blue." Why is this?

We read of a mare which, after bearing a foal to a quagga, bore a zebra-striped foal to a horse. Breeders of dogs say that a thoroughbred bitch is spoilt for true breeding if she has once been crossed by a mongrel. Is it possible that a father can influence the subsequent offspring of the same mother by a different father? This is a problem partly in scientific criticism of evidence, but it raises interesting questions regarding the physiology of reproduction and regarding the hereditary relation.

In the sixteenth century Montaigne was puzzled by the fact that, at the age of forty-five, he developed, just like his father, a stone in the bladder. The puzzle of the supposed legacy had its fine point in the fact that his father did not develop his stone till he was sixty-seven years of age, or twenty-five years after Montaigne was born! It is possible that there was here an interesting problem in inheritance; but the likelihood is that it merely illustrated the commonest of phenomena, the inheritance of a constitutional tendency and the repetition of more or less similar habits of life.

Far too much has been made of homochronous heredity!—*i.e.* of the fact that some item in the inheritance may be expressed in the offspring at the same age as in the parents. Thus two brothers, their father, and their maternal grandfather became deaf at the age of forty; blindness occurred in a father and in his four children at the age of twenty-one. But if the constitutions are similar and if the conditions of life are similar, it is not surprising that the expression of an item in the constitution should reach its climax at the same age.

A case is recorded of abnormalities in the fingers traceable

through six generations, and the pathologist Bouchut (cited by Ziegler) refers the origin of the evil to the rage of an ancestor, who terrified his wife during her pregnancy with the wish that the fingers with which she had plucked an apple against his orders might be cut off! Apart from the story's quaint suggestion of a much older episode, it requires but an elementary knowledge of the facts of heredity and inheritance to convince us that the alleged cause was inadequate to account for the effects.

In two hundred families tainted with a predisposition to bleeding (hæmophilia), which is partly due to inborn weakness in the walls of the blood-vessels, Grandidier * found six hundred and nine male "bleeders" and forty-eight female "bleeders." It is a problem of inheritance (and partly perhaps of sexual physiology) to discover why the disease should predominate in males; and the interest of the problem is enhanced by the fact that the disease rarely passes from father to son, but *usually* from a male (or female) parent, through an apparently *unaffected* daughter, to a grandson. In short, the female offspring of bleeders hand on the taint predominantly to male offspring, without themselves showing the disease.

De Candolle † reported from American statistics that thirty per cent. of the children of congenitally deaf-mute parents were deaf-mute, but that the percentage was fifteen when only one parent was congenitally deaf-mute. It is a problem of heredity to interpret the greater frequency of inheritance when both parents were affected.

While there is much and justifiable uncertainty in regard to the origin of what are called instincts, there is no doubt that an organism's inheritance often includes the power of carrying out a complex series of operations without experience and without education when the appropriate stimuli occur.

* Grandidier, *Die Hæmophilie* (1876).

† De Candolle, *Arch. Sci. Phys. Nat.* xv. p. 25, cited by Ziegler (1886).

Simple illustrations are afforded by instinctive likes and dislikes, attractions and repulsions. "So old is the feud between the cat and the dog," says Spalding, "that the kitten knows its enemy before it is able to see him, and when its fear can in no way serve it. One day, after fondling my dog, I put my hand into a basket containing four blind kittens three days old. The smell that my hand carried with it set them puffing and spitting in a most comical fashion."

Experiments with young birds hatched from artificially incubated eggs and kept away from all contact with their kind show conclusively that certain capacities are truly part of the inheritance, and require no experience or suggestion, while others not more complex require to be learnt. Thus the power of uttering the characteristic call-note is inborn, but chicks require to learn what is good for eating and what is deleterious. Thus the power of executing the proper swimming and diving movements is inherited, but chicks do not instinctively know that water is drinkable. It is one of the problems of inheritance to distinguish between inborn capacities and those which require education.

An even more difficult problem, which Prof. Pearson has successfully tackled by an ingenious indirect method, relates to the inheritance of man's mental and moral qualities. Though very plastic, there is no doubt that they are inherited in rudiment, just like physical characters. Just as the Romans distinguished physically the long-nosed Nasones, the thick-lipped Labeones, the swollen-cheeked Buccones, and the big-headed Capitones, so, as Voltaire points out, "the Appii were ever proud and inflexible, and the Catos always austere."

The literature of inheritance is crowded with examples of the transmissibility of what we cannot but call trivial peculiarities, though the probability is that they are often the correlates of what is important. A few illustrations may be selected :

"A gentleman had a peculiar formation of the right eyebrow.

It was strongly arched, and some of the hairs in the centre grew upwards. Three of his sons have the same peculiarity; one of his grandsons has it also; so has his great-granddaughter, and, *if we are to believe the artists, this gentleman's grandfather* and great-grandfather had the same peculiarity" (R. W. Felkin).

"There was a family in France, of whom the leading representative could when a youth pitch several books from his head by the movement of the scalp alone. His father, uncle, grandfather, and his three children possessed the same power to the same unusual degree. This family became divided eight generations ago into two branches, so that the head of the above-named branch was cousin in the seventh degree to the head of the other branch. This distant cousin resided in another part of France, and on being asked whether he possessed the same faculty, immediately exhibited his power."

A woman with blonde hair, a birth-mark under the left eye, and a lisp, married a man with dark hair and normal utterance. There were nineteen children, none of whom showed any of the mother's characters. Nor among the numerous grandchildren was there any trace. In the third generation, however, there was a girl with blonde hair, a mark below the left eye, and a lisp.

Girou tells of a man who had the peculiar habit of always sleeping on his back with his right leg crossed over his left. His daughter showed the same habit almost from infancy, and persisted in it in spite of efforts made to make her sleep in an orthodox position. Darwin gives an even better case where a very peculiar gesture reappeared; and there seems no doubt that trivial peculiarities, *e.g.* playing with a lock of hair and idiosyncrasies of handwriting, may reappear even in cases where imitation was out of the question (Büchner, 1882, p. 42).

And thus the list may be followed till we end with evidence of the inheritance of minutiæ often of a most trivial character. Thus: "Schook relates the case of a family nearly all the mem-

bers of which could not endure the smell of cheese, and some of them were thrown into convulsions by it" (R. W. Felkin). Here again we are forced back to the general thesis that the germinal organisation is a coherent individualised unity, which may find similar expression in the most detailed peculiarities of the body.

§ 6. *Denials of Inheritance*

The resemblance between offspring and their parents, both in general and in particular, as to abnormal as well as normal characteristics, cannot be denied as a fact, but it has often been denied *as the result of transmission.* Although the denials, which have varied greatly in degree and motive, are for the most part due to misunderstanding, they may deserve brief consideration, since even to-day we sometimes hear cultured men declaring that "they do not believe in heredity."

The extreme position may be represented by Wollaston, a scientific philosopher of the end of the eighteenth century, who sought to conserve the integrity and sanctity of the human spirit by altogether denying transmission. Each new life was to his mind a fresh start, unrelated in any real sense to parents or ancestors.

The speculative naturalist Bonnet and many others admitted the inheritance of generic and specific characters, but denied that of *individual* characteristics.

Buckle is the most illustrious example of those who, while admitting the inheritance of bodily characters, firmly deny that the same is true in regard to the mind. Buckle maintained that the ordinary method of demonstrating the inheritance of talents by collecting examples of similar mental peculiarities in father and son is in the highest degree illogical; it neglects, for instance, the frequency of coincidence, and yet more the results of similar upbringing and environment

A consideration of these denials, which have ceased to appeal to many, may be of use as affording opportunity for emphasising two facts.

1. Reappearance of a character from generation to generation does not of itself prove the inheritance of that character, *if* it be originally interpretable as the result of nurture (influences of activity and surroundings operative on the body), and *if* there be from generation to generation a persistence of the conditions which were originally instrumental in evoking the character. It is plain that the reappearance may be the result of similar effects hammered on each successive generation.

Alpine plants brought to a lowland garden have been known to become much changed, and their descendants likewise. But there is good reason to believe, as we shall afterwards see, that the novel conditions directly impressed their effects on each successive crop.

What impressed Buckle was the power of the environment in the widest sense ; it holds the organism in its grip, and hammers it into shape. This no one will gainsay, but we know that similar nurture has different results on different natures ; the duckling is not known to be less a duckling because hatched and brought up by a hen. Moreover, we know of the reappearance from generation to generation of many characteristics which cannot be interpreted as due to nurture—which often emerge, indeed, in the very teeth of nurture.

At the same time, it is of great importance to bear in mind that an organism cannot be separated from its environment except at the risk of some fallacy. We may say that along with the organic heritage contained in the germ-cells every organism has what may be called an external heritage of appropriate environmental influences, which supply the stimuli for normal development. It should be noted that organisms of quite different heritage may, under similar conditions of life, exhibit a superficial similarity—the outcome of similar temporary

adjustments or of similar permanent adaptations to the same set of circumstances, though they remain, of course, internally and intrinsically different. Thus we know that a worm-like form of body is exhibited as an adaptive feature by many vertebrates which are otherwise very unlike and very remotely related. We have only to think of the hag (*Myxine*), the eel (*Anguilla*), the amphibian Cæcilians, the lacertilian Anguidæ, and the Typhlopid snakes, which illustrate this fact of homoplasty or convergence. On the other hand, organisms of the same species may in different surroundings exhibit, temporarily, a different mode of development and growth, and a different external appearance—the phenomenon of "pœcilogony."

2. Beneath the misunderstanding which has led some to deny the facts of inheritance there is, as we have seen, a reasonable though exaggerated recognition of the potency of similar function and environment in producing resemblance; and there is, perhaps, the recognition of another fact—that of variation. For several reasons—for instance, because the new life usually springs from a fertilised ovum which combines maternal and paternal contributions—the child is never quite like its parents. In other words, we suppose that the germinal material from which a child develops is *not quite the same* as that from which the parents developed, or not quite the same as that from which its brothers and sisters developed, and the result is variation in the true sense. Each offspring has its individuality and is a new creation. Even within a family it is sometimes noteworthy that no two are alike, especially to the careful parent's eye, though the more impartial onlooker may detect certain deep-lying features in which all are alike. On the one hand, "*Alle Gestalten sind ähnlich*"; on the other hand, "*Keine gleichet der andern.*" But, however fully and clearly we recognise that hereditary resemblance is seldom complete, we find no warrant in this for a denial of the broad facts of inheritance.