EMBRYOLOGY·

CHAPTER I

THE CELL AND THE INDIVIDUAL

WHAT is Embryology, and what is its significance or interest to the ordinary educated man and woman? The answer to the question is the justification for the appearance of the following pages, and one may regard it as a somewhat striking fact, that in the production of a series of works of which this volume is one, those responsible for the subjects should have deemed it advisable to include Embryology.

Embryology may be defined as that part of the science of Biology which deals with the formation of a new individual or embryo. The definition itself ought to be sufficient to explain the significance of the subject for every one, because one can hardly conceive of any more profoundly important knowledge than that which tells of the mode of origin, manner of growth, and ultimate birth of an entirely new being. In the absence of such accurate knowledge it is quite obvious that all one's ideas concerning the manner in which the new individual is to be treated must have a more or less haphazard, or at least empirical, basis. In fact only when Embryology, or the science of the develop-

ment of the embryo, becomes a part of the ordinary everyday mental equipment of those who are responsible for bringing into the world new individuals, and subsequently protecting and handling them, will it be reasonable to expect that these new individuals will be dealt with in the best possible manner. In a word, it is evident that education, using that term in the very widest possible sense, can never be anything more than a blind groping in the dark until those into whose hands it is entrusted realise and know at least the most important fundamental facts concerning development. It is the lack of this kind of knowledge that has been responsible for so much of the mistaken systems of the past in dealing with the young, and it is the spread of this knowledge that alone is the hope of better things in the future. Wherever knowledge is absent superstition is rife, and in no sphere of life is this more painfully obvious than in connection with the subject which we are about to study. It would have been entirely impossible for many of the stupid and even cruel methods of mental and physical treatment that have been meted out to the young children in the past to have been tolerated for a moment had this knowledge been available and sufficiently widespread. For those possessing it, a flood of light is thrown upon the fascinating and otherwise obscure problems of heredity; and thus it lays open the pages of the past for those who care to read them. For those possessing it also it throws upon the mental screen pictures of possibilities in the future for all those who have eyes to see. So the study of Embryology links up the past with the present and joins the present with the future. Is it not therefore obvious that

the study of such a subject has an importance that it is impossible to exaggerate, presenting as it does problems that the parent, the teacher, the social reformer, the politician, and the philanthropist will grapple with in vain unless they call in science to the', and ? Such is the meaning and significance of the subject of our study.

In the widest sense of the word Embryology, therefore, deals with all manner of living thing- be they plant or animal. But since our purpose here is to state, as far as possible in the space at our disposal, the facts which are of particular importance in relation to the human subject, we shall only glance at the rest of living creatures. A brief look at them, however, is quite necessary in order to appreciate what follows. Let us be quite clear of what we are in search. We want to know as far as possible what it is that goes to the making of a man. What is the origin of the new individual ? Where does the embryo come from ? What elements are concerned in its formation ? Where do these elements come from ? How are they subsequently built up into the type of the species to which they belong ? From what source do they gain their nourishment ? What influences of a degenerative nature are likely to affect them ? These are the questions which it is the business of the Embryologist to answer, and these are the questions the answers to which afford the explanation of man in the making. Surely they merely require to be stated that their significance may be appreciated.

We may now glance very briefly at the simplest facts which bear upon the subject, and which must precede our detailed study. The necessity for repro-

duction and development is involved in the universal fact of death. In all except the very simplest forms of life—those consisting of one simple mass of protoplasm—the individual sooner or later perishes, and if it were not that there were some methods by means of which the individuals could give rise to new individuals obviously the species would come to an end. No matter to what great age an individual animal may live, and there are some such as the tortoises which do live for centuries, sooner or later death overtakes them, and in all, investigation of their structure shows that nature has made provision for the carrying on of the race by means of new individuals.

Every living creature, be that creature simple or complicated, animal or vegetable, man or a jellyfish, starts life as one single cell. The very simplest living individuals never consist of anything else but one single cell. and it is in these primitive forms of life alone that what we call death can not be said to occur. Such a simple cell, after living for a certain period, simply divides itself into two halves, each of which gradually assumes the size and shape of what we may term the parent cell. The first individual has simply become two separate individuals. These two in their turn after another period of independent existence, again each divide, thus giving rise to four, and so on. Now here, although the original parent cell no longer exists *as a cell*, the actual material of which it was composed still exists in the cells which came into existence as the result of this division. The original cell, therefore, may be literally said to have been deathless, or immortal, though not everlasting. This is a profound thought, and one which must be grasped

at the very commencement of our study of development, because it is one to which we shall have to recur again and again when we come to study the cells which give rise to human beings, in whom, too, there is a deathless continuity of cell protoplas. ', or germ-plasm as it is then called. It is upon this fact that the whole science of Embryology depends.

The important idea to be learned from observing this process of reproduction in the single-celled animal is this · that there is nothing here which we may term the body of an animal as opposed to any of its parts. The one cell is both body and organs, and everything else ; in itself it has the capacity of performing all the functions necessary for life, including that of reproduction for the perpetuation of the species. No part of the cell is set on one side for any special purpose such as happens in the bodies of higher animals. There are no special elements which go to the producing of the next generation, none of the cells which in a mammal, for example, we call "germ-cells." The whole individual is one cell. In fact one might almost say that there is no individual, but only race, or if we regard the cell as an individual then it is all germ-plasm. That is the important fact to be learned in the reproduction of single cells.

There are some single cells, such as those of the yeast, which reproduce in a slightly different manner, namely, by budding off a portion of themselves and finally becoming separate, and this might be regarded as a slightly higher stage, in so far as the original cell from which the bud came may be still identified ; but in reality the process differs very little from that first described.

Then we may note that very low in the scale of living things there is a process of reproduction known as conjugation, in which, although the cells of the species appear to be all alike, yet, nevertheless, two of them join together for purposes of reproduction. In other words we have here a process of cell-union before we' have the cell-division which follows. It is important to note at this stage that the creatures which we have mentioned, and even some more highly organised, such as an amœba, which has a nucleus, go through these simple or complicated reproductive processes in the total absence of anything which could suggest a distinction of sex. In these cases the individuals are obviously all of one sex, and, therefore, the distinction of sexes into male and female is evidently something which has been added later in the scheme of evolution, not for the purpose of reproduction itself, but for something which is to be added to that.

Then in the slightly higher animals and plants we come to those in which many cells go to the making of the individual, the multicellular individuals, and amongst these we very soon see the origin of what is termed specialisation of function. That is to say, in these higher creatures which consist of many numbers of cells arranged so as to form one individual, certain cells are set apart for one purpose and others for another. Some may be for digestion, some for purposes of movement, and others for reproduction. Here we have a new phenomenon, namely, the setting aside of certain cells in a multicellular individual which from the very beginning are capable of one function alone, namely, reproducing the species. The higher one goes in the scale of life the more striking and

obvious this fact becomes, and as we shall see when we come to the vertebrate kingdom, this setting aside of the cells which are to produce the individuals of the next generation is the key to the solution of the most difficult of our problems.

'In these highest forms of life, however, the cell itself is becoming a much more complicated thing than that lowly form which we first noted as dividing into two to form two new individuals. Indeed, the cells in the highest animals and plants are immensely complicated in their structures and functions; and especially in connection with the changes which take place in the nucleus of such cells. Not only the nucleus but another small object within the cell which is neither part of the nucleus nor part of the cell protoplasm, also is very important, and this structure is termed the "centrosome." In fact this little body apparently begins the whole process of cell-division by itself dividing into two parts. Then the nucleus follows suit, and ultimately the whole cell divides. The nucleus itself is a complicated structure, as is especially seen during the processes of division, in which it breaks itself up into a number of thread-like portions, and the number of these is always the same in any given species, a fact which is of great importance in reproduction. Why do we mention these apparently dry details? Because in these minute and complicated nuclear movements the whole problems which are at the bottom of development and heredity lie. The problems of life itself can only be solved by the study of what takes place in these minute portions of cells. It is here that the new formation of an individual begins, and although it is no part of our

purpose here to detail all the complicated processes of nuclear division, it is essential, in order to grasp the meaning of our subject, that we should realise that in the changes within the cell life with its variations begins.

The study of these wonderful cell processes, a work which demands the most patient investigation and high technical skill, has reached such a stage that it is a science of its own, and is called the science of " Cytology," or the science of cells, which has been made possible only in comparatively recent years by the invention of microscopes having great powers of magnification, and by the application of elaborate methods of staining to the cells themselves.

We can say no more about these processes here, but the foregoing paragraphs may perhaps be sufficient to show us how important it is to grasp these simple facts of cell life in their bearing upon development itself.

CHAPTER II

PROBLEMS OF REPRODUCTION

WE have seen that in the higher types of animals and plants the single individual is made up of not one but millions and millions of cells united together for the common purpose of the individual life, and that in such complicated individualities some cells perform one function while others perform others. A human individual from this point of view, therefore, is an organised community of cells all of which, however, sprang, in the first place, from one single cell. That original single cell is termed, in animal Embryology, the " fertilised ovum." It is popularly spoken of frequently as " the egg." All the other millions of cells are the direct descendants of this fertilised ovum, or egg, even though many of them eventually become extremely unlike the original cell. In single-celled animals the offspring of the original cell remain like the parent cell, but in the highly complicated creatures the offspring split up into a great many types of cells, owing to the very fact that all remain adherent together to form the mass of the body in order to carry out different functions. So we find cells of one type in glands, of another type in the brain, of another type in bones, of another type in blood, and so forth. Nevertheless all of them sprang from one original single cell. None of these

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specialised types of cells, however, are capable of per-forming any other function than their own. A bone-cell cannot receive an impression, nor originate an idea, any more than a brain-cell can secrete bile. Each kind of cell has its own appointed duty. The most important duty that can possibly be allotted to any cell is obviously that of reproducing the individual for the purpose of continuing the race or species. So we find in higher animals that this function, like others is relegated to a special set of cells also derived from the original single cell, and which are called " the germ-cells."

Leaving out of consideration the question of repro duction in lower types of animals we may consider the nature and origin of these cells in highest verte-brates, such as the mammals, including man. Germ-cells, which are derived from the tissues of a female animal, are termed " ova." Those which are derived from the tissues of a male animal are termed " sperms." Notice that it is not these germ-cells themselves which the terms male and female, indicative of the two sexes, are applied, but only to the individual. They are male and female; the germ-cells are of neither sex. True the germ-cells from the male, the sperms, differ in appearance when seen under a microscope from those of the female, but there is reason to believe that there is any difference betwen them in their capacity, for example, of transmitting the characters of ancestors to succeeding generations.

At a certain stage in the life history of the animal individual and after undergoing certain changes which need not be considered here, these germ-cells, both sperms and ova, have reached such a stage of maturity

as to be capable of carrying on their sole function, namely, that of reproducing the species. The actual age in human beings, for example, at which this maturity is reached varies very much in different races, and in different individuals of th same race.

"When reproduction is about to occur a union must take place between a germ-cell from a male body with a germ-cell from a female body ; that is to say, a union must take place between a sperm and an ovum This union takes place within the body of the female individual and results in the fusion of the two cells into one single cell, which is now termed a fertilised ovum. This fertilised ovum, in virtue of this process of union, is now able under suitable conditions of nutrition and shelter, such as it obtains within the female organs of reproduction, to divide and redivide again and again, thus building up a new mass of cells as the result of its division. The millions of cells so produced include, as we have already seen, cells which have all the various functions which are necessary for the continuation of the life of a human individual ; that is to say, that as the result of this division of the fertilised ovum there are produced first of all germ-cells to secure the still further continuance of the race, and then multitudes of all the other kinds of cells which gradually assume the shape of an embryo or young individual, and ultimately grow into a human being.

In all the highly complicated animals fertilisation by union of germ-cells from male and female must precede reproduction. The result eventually is this multi-cellular individual composed of a number of different kinds of cells each set apart for its own work. But it is well to recognise that we may regard all these

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cells as really of two kinds, namely, the germ-cells and
the others. That is to say, two kinds of cells are
produced as the result of fertilisation, namely, cells
whose business it ultimately will be to again take part
in a similar process of fertilisation, and so perpetuate
the species, and all the other cells which go to the
forming of the various body tissues of the individual
itself. In this way we get a simple classification of the
cells which form, for example, a human being, namely,
germ-cells and body-cells, the latter often being termed
" somatic." The latter are, of course, in much greater
abundance than the germ-cells. They have to form
all the various elements, organs, limbs, and structures
known and described by the anatomist. The germ-
cells are a separate little group of themselves embedded
in the male and female reproductive organs for the
sake of nutrition, growth, and shelter, for many years,
until they again take part in the process of fertilisation.
Note carefully that no other cells in the body ever
unite together to produce a new individual except
germ-cells.

Somatic cells reproduce by dividing directly. Germ
cells before they can do this require to be fertilised.
That is to say, the cell from the male (the sperm) must
fuse with the cell in the female (the ovum). As Dr.
Archdall Reid graphically states it, " Only the germs
are marriageable; and, as we have just seen, in the
great majority of animals and plants they observe
the degrees of consanguinity very strictly, and do not
unite except with members of another cell-community,
and then only to found a new colony of cells, an off-
spring."

There are still some further considerations in con-

nection with the subject of germ-cells and germ-plasm which we must carefully consider before leaving this part of our subject, Embryology. Everything depends upon a perfectly clear understanding at this stage. The facts themselves that have to be adduced in this connection are comparatively few and simple. No fairly educated person should have any difficulty whatsoever in grasping them. Moreover, very fortunately they are thoroughly well established and not in dispute. But the reasoning which is based upon these few and elementary facts, reasoning which is applied to the methods of treatment of the individual which is produced, may be very complicated and very debatable. Various schools of thought and opinion exist according to the attitude taken towards the facts, some of which we have mentioned and others of which we are about to detail. But the facts themselves are not debatable, and we therefore see once more that their importance at this stage cannot be exaggerated.

One or two very simple general propositions bound up with the subject of Embryology, or individual development, may be stated in order to focus attention upon the nature of the problem under investigation. Thus nobody will be found to question the fundamental truth that children resemble their parents. That is a commonplace of experience. Similarly no one will be found to dispute another fundamental fact, namely, that children differ from their parents. This, too, is equally a commonplace of experience. If we examine a million human beings we find that they all possess certain features in common, certain characteristics in virtue of which we recognise them to be human beings. Nevertheless it is just as true

that a careful examination of the same million people reveals the true saying that no two of them are exactly alike. Here then are two propositions equally true within certain limits; namely, that all human beings resemble each other, and that all human beings differ from each other. There is resemblance; and there is variation. These two things are universal because of the existence and characteristics of germ-cells. We may look at this a little closer.

Every species of animal in the process of reproduction brings forth offspring similar to itself. This is expressed in the familiar proverb that "like produces like." One does not expect grapes from thorns, nor is it possible to construct a silk purse out of a sow's ear. But what is the explanation of this proverbial fact? The answer is of great importance, because although the fact itself is recognised as a general principle in the reproduction of a species, it is not sufficiently recognised in the full details of the characters of that individual. Too many people are still apt to expect to be able to produce grapes when the plant is a thorn, and it is unfortunately all too common to make heroic but quite futile attempts to construct human silk purses out of human sows' ears —so to speak - simply because of the ignorance of the material which is being used. The most that can be done is to give such material as is present the very best opportunity of attaining its own utmost perfection; and this, by the way, is vastly more than has ever been done for any considerable number of the human race.

But why this continuity of species? Why should like always produce like? The answer has been sought

by biologists ever since problems of life attracted man's curiosity. All sorts of weird and fantastic theories have been put forward at different times to account for this simple fact, but it is only in comparatively recent years that the real explanation has been forthcoming. It is perfectly obvious that in order to secure this continuity of racial resemblance there must be something physical or material which is actually continuous from generation to generation to account for it. The immortal Darwin saw this very clearly, and devoted much thought in the endeavour to find some explanation of this very problem. The result was his theory of Pangenesis which, ingenious as it was, was ultimately shown to have no basis on fact. In his effort to account for the fact that children resemble their parents even in such minute details as the shape of the nose, the colour of the eyes, and so forth, he formulated the idea that the parents themselves probably contributed multitudes of minute particles from their own tissues to form the cells of their offspring. He supposed, for example, that particles or gemmules from the eyes, nose, hair, and so forth, of the parent, or parents, in some way or other were fused together and gave rise to the cells which ultimately produced an embryo. Hence he thought the explanation of the resemblance between parents and children. This was his solution to the question of the physical continuity between successive generations. It may be remarked in passing that it is with something of pathos that one reads in Darwin's own works his own evident opinion that this theory of Pangenesis was a great discovery. One gathers almost that he himself regarded it as of greater importance than his work on natural selection.

In the course of time, however, the real actual basis of physical continuity was shown to be something quite different, and looking back now upon the history of the discoveries in this connection during the last generation one can easily imagine what speculations there must have been in the absence of the facts which are now known to embryologists.

CHAPTER III

PROBLEMS OF REPRODUCTION (continued)

THE one outstanding discovery which has placed the science of Embryology on an absolutely firm basis, and which has made clear so many of the facts, which were previously puzzling, is this: *that the germ-cells which give rise to new individuals are themselves produced from pre-existing germ-cells.* The entire embryo, or young infant, is derived from one single cell which we have called the fertilised ovum, and that in its turn was derived from the union of two germ-cells, one from the male parent, and one from the female. These two cells in their turn were also derived in a straight line of descent from the fertilised ovum from which each parent sprang. In other words there has never been any conjugation between one fertilised ovum and another in spite of the generations of cells which have been produced between them. Put in another way the body, or somatic cells, contribute absolutely nothing to the original material or germ-plasm of which the germ-cells are composed. They do not produce them in any sense of the word whatsoever, despite the popular opinion to the contrary. This is the great discovery of modern Embryology. Until this was known it was assumed that parents did produce the cells from which their children sprang, and hence—

it was thought—the resemblance between them. The fact is quite otherwise. No parent ever produces a germ-cell, and the reason why children resemble parents and ancestors is because the germ-cells which give rise to individuals in successive generations are produced from the germ-cells of the previous generation. The line of descent or inheritance, therefore, is from germ-cell to germ-cell, and not from parents. Unless the reader makes himself absolutely familiar with the thought expressed in these facts he will never understand the science of Embryology.

Dr. Archdall Reid expresses this truth in the following words. " The somatic cells of the parent, therefore, as far as we know, contribute no living elements to the child; they merely provide temporary shelter and nutriment. The child, therefore, does not, as is popularly supposed, resemble his parent because his several parts are derived from similar parts of the parent—his head from his parent's head, his hands from his parent's hands, and so forth; he resembles him only because the germ-plasm which directed his development was a split-off portion of the germ-plasm which directed the development of the parent. The egg produces the fowl, but the fowl as a whole does not produce the egg—only one cell from the fowl, the fertilised ovum, produces it."

This is a startling thought, but it is one which a moment's careful consideration will show is the only conceivable explanation of all the facts of physical continuity. Once it is grasped a flood of light is thrown upon the whole science of Embryology. The individual is seen to be literally a " chip of the old block," and the " old block " means the whole sequence of

EGG   SPERM
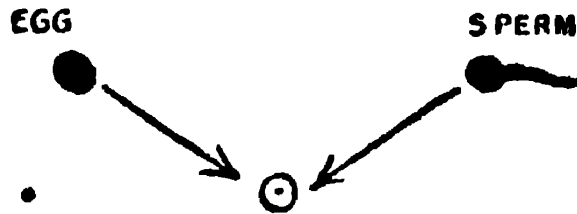
Unite in the process of fertilisation
to form the fertilised ovum, which
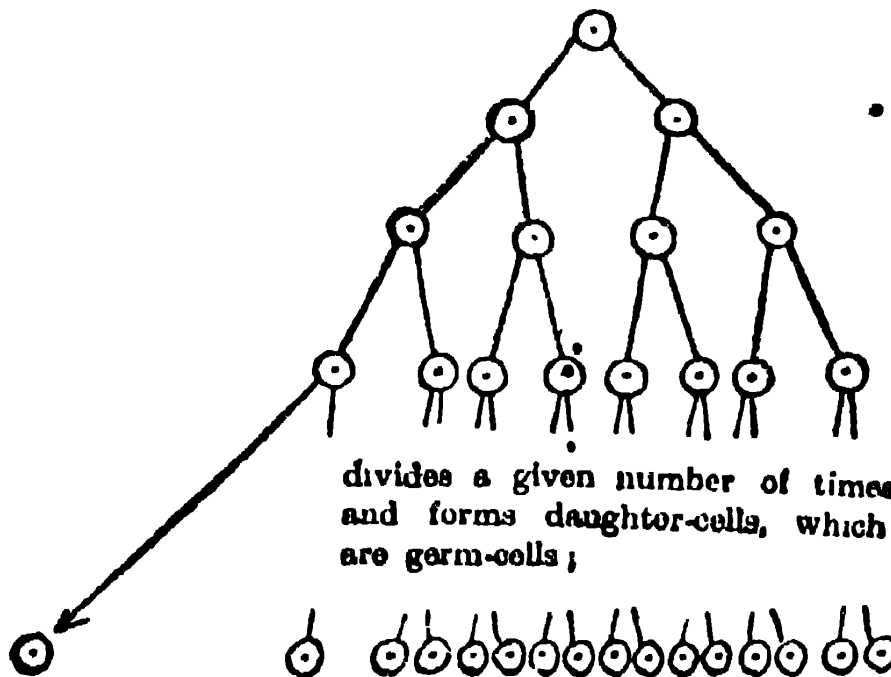
divides a given number of times
and forms daughter-cells, which
are germ-cells;

one of which, and one only, goes on dividing to form the body-cells, and so produces the new individual, which as it grows includes in itself those cells (germ-cells) previously formed. the rest are germ-cells, which subsequently form the eggs and sperms of the new individual, i.e. they are the germ-cells of the next generation. They cannot develop independently, but when they unite with the egg or sperm of another individual, a new fertilised ovum is formed and the cycle begins again.

Diagram to show the origin of germ-cells and the embryo.

germ-cells which has preceded his formation. In the light of this fact it is obvious why like produces like; indeed, it is obvious that it must do so. Further, we now understand at once that since one generation of germ cells directly produces those of the next, there is no reason in the world why an individual should not more nearly resemble a remote ancestor than his own immediate parents. As a simple matter of fact this frequently happens. He does so because the germ-cell from which he sprang is composed of protoplasm handed down in direct continuity by successive generations of germ-cells from time immemorial. In fact the problem in the light of this evidence is not so much—as it always seems to the writer—to understand why children resemble parents and ancestors, as to understand how it is that they do not resemble them more.

There is no difficulty now in explaining the fundamental propositions with which we started, namely, that children resemble their parents. There is no difficulty in the understanding why a child resembles not only its immediate parents, but even its ancestors. There is even no difficulty in understanding why a child should resemble its ancestors, even though it does not resemble its parents. Given the simple truth that the germ-plasm is continuous from one generation to another, all these things become as clear as daylight.

But we also start with another general proposition, namely, that children differ from their parents, and it is this question of the variation in offspring which must now claim our attention for a moment. By this term we mean to convey the fact that although every child has a real resemblance to its parents or its

ancestors, it inevitably and invariably shows differences even if these be more minute than the resemblances. In other words the offspring of a human being, though obviously and necessarily, from the continuity of germ-plasm, it must be another human being, is never exactly similar to any other. Now these variations are many of them present from the very beginning, they take their origin in the germ-plasm of the two germ-cells which form the fertilised ovum. They are, that is to say, many of them germinal in origin. These must be carefully distinguished from such characteristics as are afterwards acquired by the child as the result of its adaptation to the environment in which it passes its existence.

It would be beyond the scope of the present work to enter into all the various theories which have been put forward to account for the fact of variation. It will be sufficient for our purpose here if the reader remembers that it is a universal tendency in all living protoplasm to exhibit variations. It is just as universal as is its continuity of likeness. Moreover, in dealing with the highest animals in which the fertilised ovum, from which the embryo springs, is produced by the union of germ-cells from male and female, one may readily understand that the different lines of descent of the male and female germ-cells may well be responsible for the differences exhibited in the offspring. Obviously the fertilised ovum, if it has to give rise to a normal individual, cannot retain *all the characteristics* which were possibly existent in both the male germ-cells and the female germ-cells. Some of them must be suppressed or got rid of, otherwise there would be too many characters in the resulting offspring.

And, as a matter of fact, such a reduction does actually take place in the physical tissue comprising the fertilised cell, and it is probably at this stage that variations take their origin.

Thus, for example, it is quite impossible that two opposing characteristics can both be represented in the fertilised ovum. One of them must be suppressed or thrown out or got rid of in some way or another. For example, the union of the male element and the female element will give rise to an embryo which may be eventually either a male or a female individual, but cannot be both. There were possibilities of it being either the one or the other at the beginning, but since the two possibilities are mutually antagonistic, one or the other must be eliminated. So again, supposing that the colour of the eyes on the one side were brown, and on the other side blue, the possibilities are that the fertilised ovum may give rise to an individual having either blue eyes or brown eyes, but, again, not both.

A variation in offspring then may be regarded as a difference between that offspring and the parents, which is due to some change in the germ-plasm, some difference, that is, between the germ-plasm from which the parent sprang and that from which the next generation arose. Such differences will, of course, be introduced at the time of fertilisation. It is important to keep clearly in mind the difference between a true variation, in the sense that we have just used the term, and a modification which is caused by the varying effects of influences affecting parents and offspring. Unless these two things are kept mentally distinct, much confusion of thought is apt to arise.

The above statement does not necessarily mean that the germ-plasm carried in the sperms and the ova respectively, cannot be affected in any way. Indeed one is forced to the conclusion that such germ-cells must be influenced by the nutrient fluids supplied to them, and by the existence of toxic or poisonous substances in the body of the parent. It is quite conceivable, and indeed inevitable, that the individual embryo resulting from the fusion of such poisoned germ-cells will show modifications, but these, however, are not to be regarded in any sense as true variations, for the simple reason that these modifications do not take their origin in the actual germ-plasm itself, but are simply the result of abnormal stimuli. Such modifications, no matter in what direction they may be, are, of course, not transmissible to the next generation, for the very obvious reason that the germ-cells which are to be concerned with the next generation have been already produced. The germ-plasm itself passes on unchanged in so far as its hereditary possibilities are concerned. We see, therefore, that in order to think clearly on this matter we must limit the meaning of the word variation to such differences or changes in germ-plasm which indicates some real change of an inheritable nature. The term should not be used to apply to a mere passing environment, in which the germ-plasm happens to be, caused by the presence of poisons, or similar factors.

Given then the fact that variations do constantly and inevitably occur in offspring owing to new qualities arising in germ-plasm itself, it is obvious that these variations are either what are termed " spontaneous," or else they must be due to the action of the sur-

roundings on the germ-plasm. By the term "spontaneous," in this connection, it is not meant that these variations arise without cause or in a haphazard manner It is simply meant to imply that the present state of our knowledge does not justify us in stating what does actually cause the variation in germ-plasm, or the law in accordance with which such variations occur That they must be a matter of cause and effect and law every biologist believes, but until the law can be demonstrated the term ' spontaneous " may well be retained to distinguish these variations from those which arise by the obvious action of environment For example the variations which occur as the results of reproduction from two parents do so because of the mingling of the respective germ cells, and such variations come under the group of " spontaneous "; whereas changes induced on account of the food supplied or poisonous substances in fluids surrounding germ cell are not spontaneous but environmental.

A point of great interest to the embryologists is the question whether the differences of detail which exist between children and their parents are of the nature of spontaneous variations, taking their origin in the germ plasm itself or mere modifications produced by the action of the environment of the embryo. Further should both these factors play a part in producing the differences, which is of greater importance, and in what proportion ? This question is elaborated in great detail by Dr Archdall Reid, in his work, *The Laws of Heredity*, which ought to be read by every intelligent citizen and parent who is interested in the welfare of the young In the main in this subject we follow the ideas so ably put forward by him. He

points out that the offspring of the same parents always differ not only from the parents, but among themselves, even if they be twins, and amongst the lower animals every member of a litter of dogs, or pigs, or kittens, shows differences in size, colour, activities, temperament, and characteristics. Are those differences due to the action of environment on the embryo or do they take their origin in the germ-cells from which the individuals came ? Inasmuch as a litter of puppies is subjected to precisely the same environment during the whole time of development, it is perfectly obvious that such differences as they exhibit at the time of birth must have been germinal, an identical environment could not by any stretch of the imagination be held responsible for producing variations. They, therefore, must be of the spontaneous variety. Of course it may be argued that even during development the environment of each embryo within the mother is not identical, but it will be a gross abuse of such argument to therefore conclude that such minute differences of surroundings could account for one puppy being big and black, and another one small and brown in the same litter; or that one should resemble one parent, another the other, and a third a remote ancestor. It is, therefore, clear that *some at least* of the variations in offspring are germinal or spontaneous in origin, and not in any way due to the environment of the embryo.

The question remains whether all variations are due to this cause or whether some may be traced to environmental factors. One of the best lines of argument and investigation on this point is that of the bacteriologist, because microbes with which he is concerned

may be regarded as equivalent in this matter to germ-cells, all microbes being unicellular. The problems of the germ-cell, and its heredity, therefore, are very similar in both cases. Tried by this test we may ask whether the changes produced in these unicellular organisms by the action of their environment are, or are not, inherited as variations. No one doubts for a single moment that a microbe as well as a germ-cell may be changed, or injured, or improved, according to its own special environment. What is in dispute is whether that change remains fixed in the succeeding generations to which these unicellular cells give rise. It is precisely here that the bacteriologist can offer evidence of a most important character. He will tell us that it is quite easy to change many of the characteristics of a microbe by altering its environment, which is undoubtedly true, but the further statement that they change because their germ-plasm is affected directly by the environment is not necessarily true. These organisms and germ-cells are composed of protoplasm whose ultimate constitution permits of their varying spontaneously. These variations are obviously to enable them to adapt themselves to the tissues of the animal in which they are living, and these variations also, or modifications as they really are, are usually lost when that environment is no longer existent. In other words they proceed no further than to allow the microbe to exist in a new environment. This seems to point undoubtedly to the fact that they are caused by selection of true variations. In other words what is ultimately produced is a condition of the germ-cell in which it becomes very highly resistant to any influence immediately exerted upon it

by the environment, and so continues to live in successive generations without any further modification. The conclusion, therefore, is, in Dr. Reid's words, " that the germ plasm is both spontaneously variable and highly resistant to the direct actio f the environment. In other words we must believe that in any species that is not undergoing extinction spontaneous variations greatly preponderate over those which are caused by the direct action of the environment."

This quality of single cells, that is to say of the germ-plasm of all species which continue to exist, in virtue of which it resists very strongly any efforts to change it, is a very important matter to gra p Without it it is quite obvious that no species could maintain its characteristic features for any length of time. Were it not for this resistant power germ plasm would be easily destroyed or continually and readily changed. The descendants from such continually changing germ-plasm would themselves be of such infinite variety that there would be no such thing as a definite species, so that there is no doubt whatever that germ plasm has become, probably by the action of natural selection, extremely resistant to all influences of an environmental character.

That does not mean, of course, that germ-plasm cannot be damaged, or weakened, or changed in its tendencies. It does mean that when it is so changed it is principally as the result of injury, which may be indeed so severe as to destroy the germ plasm itself. It would seem as if the inherited tendencies of germ-cells were so intimately bound up in the constitution of those cells as to be almost a matter of life and death of the cells. If they be so interfered with as to be

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destroyed it is hardly possible for the cell itself to continue to exist. One of the most interesting examples of this resistance of germ-cells to their environment is in connection with some human diseases which have existed from time immemorial, diseases the descriptions of which are to be found given quite accurately in the most ancient documents, but in spite of the fact that human germ-cells have been subject to the hostile surroundings which such human diseases involve they themselves have not changed to any great extent. That is to say they still produce a type of embryo and offspring practically identical with that that always was produced.

The same truth applies to the cells which make up the body of the embryo and the individual, as well as to the germ-cells. The body cells, those which make up bone, and muscle, and gland, and so forth, are constantly exposed to all sorts of influences which must tend to damage them so far as it is possible for the cells to be damaged and still live. These body-cells are sometimes starved, sometimes poisoned with alcohol and drugs, frozen by extremes of temperature, over-worked by too much physical strain, and so on, and if it were possible for such external influences to change the type of cells of their offspring we should expect to see it here. But it does not occur. The internal hereditary tendencies of these cells are so strong, and so intimately bound up with the life of the cells themselves, that when they divide and produce others these others are precisely similar to the parent cells, in spite of all the unfavourable environment in which they have been. Slight variations do, of course, occur, but these are chiefly of a germinal or spontaneous nature, and not due to the environment.

This thought gives us some vague and imperfect idea of how immensely complex the constitution of germ-plasm must be. This germ-plasm is very often subjected to all sorts of unfavourable conditions, especially those of alcohol and toxins, and such conditions have been acting upon it more or less for an immense number of generations, and yet the resistance to modification at the hands of these internal factors is so great that all the processes which follow upon the fertilisation of the ovum, all the thousand complications which thereafter ensue in the building up of the young embryo are hardly ever interfered with. When they are markedly interfered with such interference generally involves the death of the embryo.

The conclusion arrived at on this subject by Dr. Archdall Reid, after a very careful and extensive inquiry into all the evidence from many points of view, is stated by him as follows : " Though variations may result from the direct action of the environment, such variations are, in effect, always injuries, and are of rare occurrence in individuals who survive and have offspring. Adaptation (i.e. evolution) depends almost exclusively on spontaneous variations. These do not imply damage to the germ-plasm, but are products of its vital activity. Occurring in vast abundance all round the specific and parental means, they supply the sole material for Natural Selection.

" We conceive the germ-plasm, then, as living and active, closely adjusted to its environment, growing, dividing, varying, capable of being destroyed and injured, but resisting death and injury, and within limits capable of repairing damage and returning to its original state—as behaving exactly as a living individual does."

CHAPTER IV

THE MAKING OF A MAN

HAVING, in this brief preliminary consideration of the fundamental facts upon which the science of Embryology is based cleared the ground as far as possible, we may now summarise, in a few simple statements, the point at which we have arrived in order that we may proceed at once to the more detailed study of the actual development of the embryo itself.

We are in search of as clear a statement as possible of the origin of the many and varied characteristics which go to the formation of a human embryo, and hence to the making of an individual. The variation in these many characteristics accounts for the differences in individualities. No two individuals are exactly similar whatever be the standard by which we estimate them. This is true morally, ethically, and physically. In each of these spheres there are to be found good, bad, and indifferent individuals, but whichever they are it is quite obvious that the result has been brought about by the influence of all the factors of heredity and environment acting upon the capacities which were originally implanted in the germ-plasm. An individual is the resultant of the play upon one man's-worth of human material of all forces which have acted, or are acting, upon that kind and amount of

material. Even though two children of the same parents be brought up under what are to all appearances identical circumstances, they differ from the very beginning from each other and their parents. This is true even of physical characteristics, and even more markedly in mental features. The fact is—and it is one which is not sufficiently recognised that the formation of an individual from an embryo, the making of a man, is a biological problem fundamentally.

The following are the principal facts which we have at this stage to bear in mind.

All living creatures are made of cells, the physical basis of which is protoplasm. The simplest creatures consist of one such mass of protoplasm; higher organisms consist of more than one, and often of millions, in which case they adhere together. Cells multiply by dividing into two, the protoplasm of the mother-cell giving rise to that of the daughter cells. A human embryo, therefore, which is going to give rise to an adult individual is a community consisting of an enormous number of cells, the whole of which have descended from one common ancestor, a single cell known as a fertilised ovum. True, these descendants break up into many types of cells in order that different functions may be performed by special tissues, but none of these special cells can do everything that is necessary for the life of the whole individual; they can only play their own special small part. They can do nothing towards continuing the species of the individual. This duty, like others, is imposed upon one particular group and kind of cells, namely, the germ-cells, which do nothing else in the animal economy but furnish the means for the continuity of the race.

Although they lie within the tissues of the embryo, and afterwards of the adult, they take no part in the life of that embryo or adult. They undergo certain changes in themselves which are to fit them for their ultimate destiny and function, but they contribute nothing to the output of energy on the part of the individual.' When these are derived from a female they are termed " ova " ; when from a male they are termed " sperms." They themselves are neither male nor female, they are merely protected and nourished by the general mass of cells which constitutes the male and female individual.

When a male germ-cell or sperm unites with a female germ-cell or ovum, within the female body, fertilisation of the ovum takes place, and this gives rise to the fertilised germ-cell from which is to arise first the germ-cells or direct descendants of itself, and secondly the embryo in which these germ-cells will come to lie. This happens by the repeated and continued division of the fertilised germ cell, a division which constitutes growth, and which under suitable conditions of nourishment and protection and exercise will ultimately produce a human being. The great mass of the cells of this individual, the body or somatic cells, take no part whatsoever in giving rise to the germ-cells of the next generation. These are produced from the pre-existing germ-cells, and from no other source, and it is for this reason alone that the phenomena of heredity are possible and that one generation is directly continuous with its predecessors. In fact heredity may be defined as the relationship which exists between successive generations.

We therefore see that the embryo, or the individual, is formed from one, and one only, of the first products of the division of the fertilised germ-cell, the rest of these products forming the other body tissues. This idea of the continuity of the germ plasm is the greatest contribution of modern embryological research. It is quite fundamental, and no clear understanding of what is involved in the making of a man is possible without it. It teaches us that the line of ancestry and heredity is from one generation of germ-cells to another, directly, and never through the individual from the embryo, which, indeed, is a mere side product in the continued chain of events. The individual is practically the trustee of the germ-cells, but not their maker. No embryo, and no individual, ever made germ cells; the latter existed first. The object of the embryo is obviously to protect and nourish the germ-cells which have been placed within it, so that they may be available in due time for the production of further germ-cells, and so for the continuity of the race. Hence it is the all-pervading truth of natural selection that the interest and survival of the individual is almost of no account; that of the species or the race being the paramount consideration.

Once these facts be grasped there is no longer any difficulty in understanding why the process of reproduction in any given species always results in the formation of embryos which resemble each other in all the main characters of their species. It could not be otherwise, because they come from portions of identically similar material, a common germ-plasm. In other words, the individual inherits nothing from its parents. He merely receives in his turn the material

inheritance in the germ-plasm which was there a generation before him.

In so far as there has been no germinal variation. he and they will be similar. Hence the common observation that the child resembles the parent. True, so he does. but not because he gets his characters from them but simply because he and they obtain their characters too from a common source. To many this thought will be perhaps a new one. It is one of the most interesting ideas which science has given us, and in its absence no real grasp of the origin of the physical mental and other characters if there be any, of the embryo can be understood. The present writer has elsewhere summarised this thought as follows :—

" Man is composed partly of characteristics, which are derived from pre existing germ cells and over the possession of which he has no control whatsoever. Be they good bad or indifferent these characteristics are his from his ancestry in virtue of his inheritance. The possession of these characteristics is to him a matter of neither blame nor praise but of necessity. They are inevitable '

The embryo then which is to form the individual starts its career with a certain number of innate germinal characteristics which manifest themselves in the form of tendencies to grow in this direction or that. During the period of gestation a good many of these tendencies are well developed while a good many more only manifest their exact nature in later life. But it is upon the basis of these tendencies—and upon no other—that the making of the individual is possible. They represent the total assets available for the formation of character. Nothing of any new kind can be added to them.

All that can be done under the best conceivable circumstances is so to arrange the environment and surroundings of the embryo, and the subsequent individual, so that these tendencies are acted upon in such a way that the best are developed and the worst eliminated. It must be remembered that it is under the constant action of everything that constitutes the environment of an embryo that the mass of body cells gradually grows into a recognisable human personality.

The question then arises, What are the factors external to the embryo which cause these germinal tendencies to become active and fully developed? These factors are those of (a) nourishment; (b) use, or exercise; and (c) injury. In the case of the human embryo by far the most important of these three factors is the first. A proper supply of nourishment and food, that is to say maternal nutrition of adequate quantity, is sufficient up to the time of birth to cause the inborn tendencies in all the body-cells gradually to assume the special characteristics of muscle bone, gland, nerve, and so forth, which make the human embryo. After the period of embryonic life is over, the stimulus of nutrition is still sufficient for some of these body-cells. Thus we find that the hair, the teeth, the internal ears, and the organs of reproduction, all grow to their full development in the absence of any other factor or stimulus than that of nutrition. But, as we also know, this simple stimulus is not sufficient for most of the other body tissues to develop properly. They require the additional stimulus of exercise which, indeed, may be said to begin even in the life of the embryo. After that it is quite hopeless to expect a healthy embryo to develop into a fine child unless to the stimulus of nutrition there is

added that of exercise. It is from the varying quantities and qualities of the three factors of nourishment, exercise, and injury, that part of the explanation is found for the variation in individuals of the same family. Starting with a good many of the same inborn tendencies none of them afterwards receive quite the same kind and amount of these stimuli, under the action of which they develop. And so we reach the second point, namely, that, in addition to innate characters certain others are subsequently acquired by the embryo of the individual in response to particular stimuli acting from without.

Here we are upon ground which is more or less in our own choice or control. It is impossible to alter germ-plasm; but it is not impossible to control the environment in which it exists. To these two groups of characters, the germinal and those acquired under stimulus, there is to be added the third group which we have mentioned on a previous page, namely, those that are usually termed variations. For example, one occasionally finds that one individual in a family, the parents of which, and the other members of which, are quite normal, may be born with six fingers instead of five. Similarly one of a family may have a variation in the direction of an extraordinary capacity for the acquisition of knowledge of certain types. Hence the genius in music, mathematics, memory, morality, and so forth. As we have seen, these variations are termed spontaneous, to express the fact that we are at present ignorant of the laws in accordance with which they arise, though, of course, it is understood that those laws must exist.

We have now surveyed the whole field of the possible

origin of the characters of an embryo, and these may be summed up in the following tabular statement.

An Embryo is made up of

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A. Inborn Characters—
*   (a) Inher ted (grow ing under the stimulus of nutriment).
   (b) Variations.
B. Acquired Characters, obtained
   (a) By nutrition.
   (b) By use.
   (c) By injury

The differences in individuals with which we are also familiar, are due to the varying proportions of the characters in the above table, and the characters themselves are those which constitute all the possibilities for any given person.

Should the reader doubt this, or be sceptical as to whether the whole of the making of a man is contained in the above simple scheme, it would not be difficult for him to convince himself that the statement is a true one. Let him put down this book and take a sheet of paper and a pencil. Rule the sheet of paper into three columns, and at the top of each column place a heading as follows : Inherited; Acquired; and Variations. Thus :—

Inherited.	Acquired.	Variations.

Let him then proceed to think of as many definite characteristics of his own as he possibly can, and then enter these characteristics in the column which he deems appropriate. It will be found that with the great majority of characteristics no difficulty will be presented and it will be quite impossible to think of anything which is a physical part of himself, which cannot be placed in one or other of these three categories. Even though there may be a little difficulty as to which column should claim the entry, it will be found that this is due rather to indecision on the part of the reader than to anything else. It is not because he can imagine any other origin for the trait which is for the moment puzzling, but simply because he may be uncertain as to whether it is an inborn character, or one due to the subsequent action of circumstances. Thus he will have no difficulty in placing in the first column such characteristics as the possession of one nose, two eyes, the colour of his eyes, perhaps the shape of his nose, and so forth, these all being germinal inherited characters. Equally simple is it to see that in the second column must be placed such parts of his individuality as speech, writing, the size of his muscles at the moment and so forth. These, obviously have resulted from the action of circumstances on inborn capacities. No embryo can speak or write, though it has within it the inherited capacity to enable it to learn such things. Finally he may find it difficult to think of anything to place under the heading of " Variations "; but, on the other hand, should he happen to be a genius in music or mathematics, or the possessor of six toes or a black mole on his arm, these will indicate to him at once

that they are of the nature of " Variations." (It must be remembered, however, that they may be transmitted to successive generations, in which case they become germinal characters.)

In a similar way if the reader desires to follow out this analysis of the characters which make an embryo, and which, therefore, afterwards comprise the possibilities of an individual from the point of view of the stimuli under which they are developed, he may easily do so. Another sheet of paper similarly divided into three columns with the headings " Nutrition, Use, and Injury," will enable him to see how his individual characteristics have attained their present development as the result of one or other of these stimuli acting upon the germinal or inherited tendencies. Without going into detail in this matter one may simply note that under the heading of " Injury " will come all those parts of himself of which he has become possessed as the result of disease or accident, whether this be physical, mental, or moral.

Now we have completed what was necessary to arrive at our conclusion of what it is that goes to the making of an embryo, and therefore of a human being —a personality. The conclusion is that every characteristic which it is possible for an individual under any circumstances whatsoever to possess is traceable ultimately to the action which takes place between his inherited tendencies and his natural environment. This environment, whether it be physical, mental, moral, ethical, spiritual, or whatever other can be imagined, can only produce the whole individual by means of acting upon what is already present. To that material nothing can be added *except in the environ-*

ment; from that material nothing can be taken away; the most that can be done in this direction is to hinder its growth by suitable procedures. Hence the truth of the phrase that "education is nothing more than the giving or withholding of opportunity." Hence it is so entirely true that it is impossible to make a silk purse out of a sow's ear, or to gather grapes from thorns. The importance of thoroughly realising these simple facts of embryology should at this stage be obvious. They constitute possibly the most important lesson which is demanding attention at the hands of modern teachers, parents, and sociologists.

One further word before we leave this part of our subject. It is obvious that of our total characteristics some are acquired and some are inherited, and the question then arises. How much is inherited in an embryo or individual, and therefore unavoidable, and how much acquired ° It would be beyond the scope of our subject in this place to enter into detail in this matter, but it would not be right to pass the question by without pointing out that a careful analysis of individual characteristics will show that under the heading of "Inherited" will be found principally the physical traits. When the reader comes to estimate his mental and moral characteristics, a very few moments' careful thought will prove most conclusively to him that these must be entered up under the heading of "Acquired." If it were not so progress in those directions would be practically hopeless. But plain as is this truth, it is one which is far from being realised by many well-educated people.

CHAPTER V

FERTILISATION AND EARLY DEVELOPMENT

WE may now turn our attention to the consideration of some of the phenomena connected with the early processes in the development of the embryo. We may assume that the eggs and sperms have reached such a stage in their life history that they are now mature. All that is necessary in order that the development of an embryo should result is that union of the two elements should take place. Many complicated changes have occurred in the constitution of these eggs and sperms before this stage is reached, but into these we need not enter. It will suffice for our purpose to assume that they are now mature. Then as the result of a natural instinct which suggests certain thoughts and emotions to the male and female animals, which in turn are followed by certain definite acts, the sperm-cell from the male and the egg or ovum-cell from the female are brought into contact. This contact takes place in such circumstances that the united elements are able to be protected and nourished and so, fertilisation having thus occurred, development begins.

The characters of these two wonderful cells, which by their union ultimately cause the production of an embryo, are briefly as follows. The element from the male, the sperm that is, is an extremely minute cell

which is only about $\frac{1}{500}$ of an inch in length. As seen under a high power of the microscope it is composed of two portions which are spoken of as a head and the tail The former is a flat oval part, and behind this is the rounded body ending in the long tail which is some four fifths of the total length. This long tapering tail gives to the sperm its power of movement for it is supposed that as the result of the rotating or lashing movements of this tail the cell is propelled Indeed its rate of motion has been actually studied, and estimated to be at about one eighth of an inch per minute.

The cell contributed by the female, the ovum that is has quite a different structure and microscopical appearance Compared with most cells it is rather large almost round in shape having a diameter of about $\frac{1}{12}$ of an inch. Up to the time we are now considering this cell along with a great many others like it, has been stored within the female ovary, from which organ an ovum periodically escapes Unless fertilisation takes place by union with a sperm the discharged ovum perishes Should however the sperm-cell be available and should it have been able to reach a situation at which fertilisation can take place within the chain of events which constitute development begins But before fertilisation can take place the ovum has undergone what is called the process of maturation in which it divides twice, giving off two small portions of itself in the process. The result of this is that half the number of chromosomes in the ovum are lost This process of maturation has already taken place in the sperm before it leaves the body of the male.

When these two cells meet, the actual fusion of their material takes place, the head of the sperm penetrating into the substance of the ovum, and the body of the sperm completely fusing with the nucleus of the ovum. This gives rise to what is called the segmentation nucleus." It will be observed that we now have a cell in which the full number of chromosomes for that particular species is represented once more But this full number has now been made up from two different sources half from the elements contributed from the male and half from those of the female It is at this stage that the inherited tendencies, carried in the germ-plasm on the two sides of the ancestry, become mingled, and from thenceforward the division of the fertilised cell into many cell descendants goes on with extreme rapidity

Two different lines of germ plasm have thus been intimately mingled and the actual significance of this mingling has given rise to one of the most acutely debated points in all the problems of heredity Put into quite plain language that problem is—What is the function of sex ? It is no part of our task here to answer that problem but it is of interest to point out precisely at what stage it occurs in embryology The obvious answer, however, may be advanced that the function of sex is to mix the characters of the parents in such a way that some from each source will be found in the offspring But how these are mixed whether as painters mix two colours and produce a third, or as two packs of cards are mixed having different coloured backs, is quite another matter

The fertilised ovum now commences to form a number of successive generations of cells, and this it does by

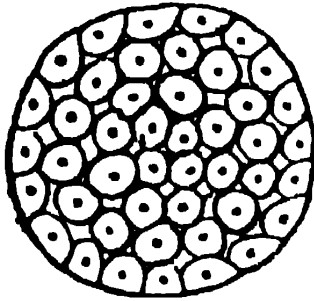dividing into two, four, eight, sixteen, thirty-two, and so forth, until a number of cells have been produced which arrange themselves into the form of a ball. The surface of this ball resembles that of a mulberry, each elevation corresponding to a cell. This mass is termed by embryologists " the morula." (See Fig. 1.)

Next, within this morula some of the cells become condensed into one particular portion, leaving a space which contains fluid. The ball is now no longer solid, but has a portion consisting of cells, and a portion consisting of fluid. It is now called a " blastocyst." (See Fig. 2.)

' FIG. 1.

The cross-section of this shows the cells projecting into a cavity. This is the first attempt of the fertilised ovum to form itself into the different layers, which are ultimately going to give rise to all the different tissues of the embryo. But it is interesting to know at this stage that the outer layer of cells, those representing a margin in the figure, has nothing to do with the forming of the embryo at all, but gives rise to a structure whose function afterwards is to be that of nourishing the growing embryo.
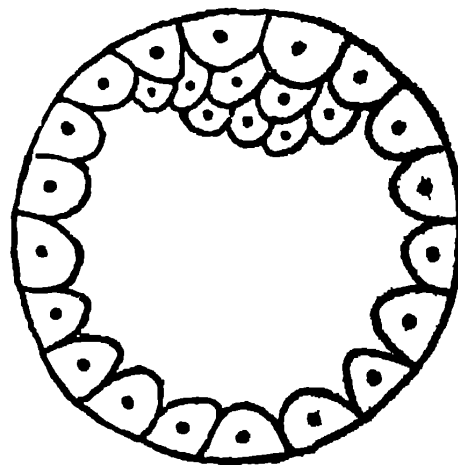
FIG. 2.

The next obvious change is that the cells at the lower portion of the mass which projects into the cavity

appear to get flattened out—at any rate they obviously
arrange themselves in a definite and separate layer;
and this layer in its turn proceeds to go on growing by
division of its cells in such a way as to form another
little closed cavity within the larger one. This cavity
is termed the " yolk sac." (See Fig. 3.) Then another
little cavity occurs, this time within the original pro-
jecting cell-mass. This cavity is termed by embry-
ologists the " amniotic cavity," and the cells which
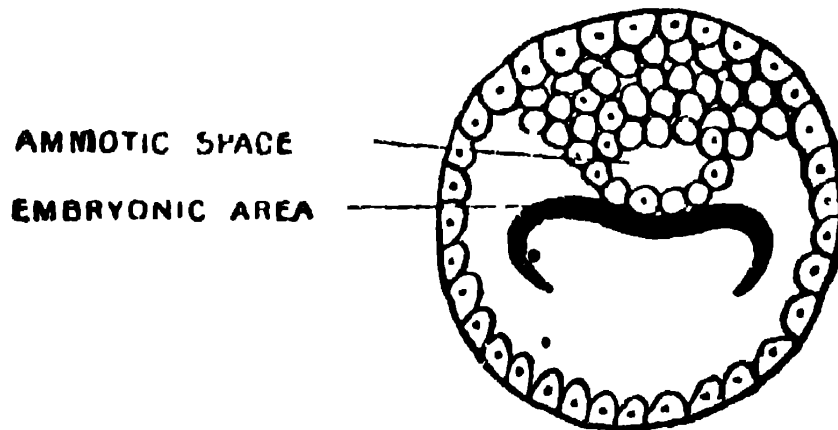
AMNIOTIC SPACE

EMBRYONIC AREA

FIG. 3.

line it, and which in their turn become arranged as a
separate layer, form what is termed the " embryonic
ectoderm." (See Fig. 3.)

It is in this region, and in that of the yolk sac which
lies just underneath it, that the future growth of the
embryo itself occurs, and the portion is therefore
termed the " embryonic area." (See Fig. 3.)

Up to this point we have seen that two layers of
cells have appeared, one round the yolk sac, called the
" entoderm," and the other lining the amnion, called
the " ectoderm." After these two germinal layers
have made their appearance, a third layer comes into

existence, which, because it begins growing from the embryonic area, and lies between the two already mentioned, has received the name of the "mesoderm." This third germinal layer divides into two portions before very long, and the space between these two is that in which the body cavity itself subsequently arises. One part of the mesoderm, situated near one end of the embryonic area, is specially important, because in it are formed the blood-vessels which supply the embryo, and which ultimately afterwards becomes the "umbilical cord," which forms the connection between embryo and mother.

CHAPTER VI

EARLY DEVELOPMENT

THE early development of the embryo now proceeds rapidly, and its appearance at the stage we have just been describing is thus stated by Dr R W Johnstone —

― "If the ovum at this stage be looked at from above, the embryonic area appears as a small shaded oval. The shading is due to an increased growth of cells, because here the three germinal layers—embryonic ectoderm, mesoderm, and entoderm—are in contact. At one end a patch of darker shading indicates a still greater growth of cells. Running forward from this is a band—the *primitive streak*—in the centre of which lies a darker line—the *primitive groove* At the far (anterior) end of the primitive groove there is a dark spot—Hensen's node—from which still another streak runs forward, the head process. Later, in front of the primitive streak, a thickened band of ectoderm appears, broadening out posteriorly. The edges of this band rise up to form two folds which meet anteriorly. The groove between them is the *medullary groove*, and ultimately they fold over and unite to form the *neural canal*. (See Fig. 4)

" Along the line of the primitive streak all three germinal layers are in contact. Superficial to it is

the amnion, and below it is the yolk sac. The embry-
onic area is the only part of the ovum which has to do
with the subsequent development of the embryo;
the other parts of the blastodermic vesicle become
subservient as nutritive or supporting structures.

" At this stage, and for the first three weeks of its
existence the embryo is a 'flat disc floating on the
surface of the yolk sac.' (M Murrich.) "

This is followed by a folding of the embryo, due to
the enlarging of the amniotic cavity, the result being
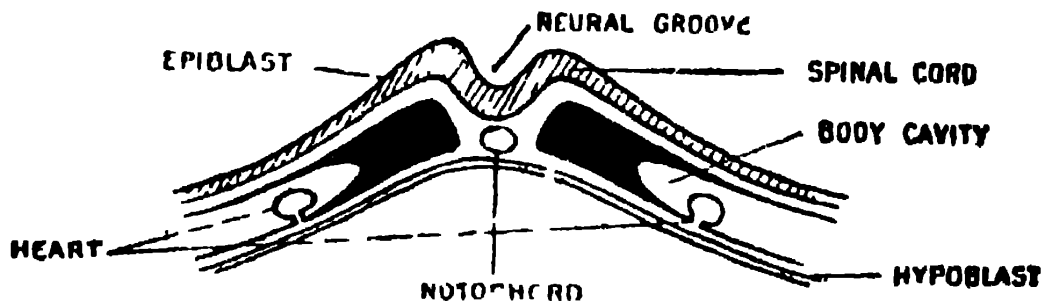to form what may be termed a " head-fold " and a

FIG 4.

" tail fold " A further fold, however, occurs at the
sides which bend in, so that the whole embryonic mass
at this stage comes to form an incomplete tube, the
incomplete portion being the lower aspect of that
tube. This remains open. In due time this lower,
or ventral portion, becomes completely closed, except
just at one point. This point is where the communi-
cation exists between the inside of the tube, which is
the embryo, and the yolk sac. A part of the yolk sac
is thus included in the embryo itself, and this has an
important bearing upon future development, because
in the course of time this part comes to be the alimentary
tract of the growing embryo. The canal which joins

the yolk sac to the internal gut of the embryo (the vitelline duct) ultimately forms, together with part of the yolk sac, the umbilical cord. This cord, which at the time of birth is artificially severed in order to free the fully developed embryo, is at this stage connected to the hinder part of the body or the embryo. As the latter grows, however, it elongates still more behind, in what we should regard as the tail region in animals which had a well-marked tail. As a matter of fact, at a little later stage than this there : quite a conspicuous tail in the human embryo, which, however, comes to be embedded in the tissues later on, and so never forms any external appendage.

So that at this stage we have the embryo representing a mass of cells which have gradually arranged themselves, and been arranged, in the form of a tube more or less bent, and attached near its hinder end to the tissues which are afterwards to represent the umbilical cord.

We have neglected to describe the organs and structures which are developed after fertilisation as a further means of protecting the developing embryo. We have done this of set purpose, because these structures —known as the " trophoblast "—require a considerable amount of technical knowledge to understand. Any detailed description of them, therefore, would be out of place here. All that is necessary for us to say is that they are intended to serve as a means of nutrition for the developing embryo, and take no part in the actual formation of its cells and organs. One portion of it, however, has another function which may be mentioned. It secretes, it is supposed, a kind of ferment, which has the power of dissolving or digesting

other cells, and this is of great importance at one stages
of development—namely, when the fertilised ovum
comes to reach the womb, or uterus, in which it is to
pass the rest of its developing stage It is believed
that some of the cells in the wall of the uterus are dis-
solved and digested immediately round the ovum
itself, which thus comes to he in a cavity in the uterine
wall This process being carried still further allows the
ovum to sink deeper and deeper into the lining mem-
brane of the uterus Ultimately the point of entrance,
where the cells were digested is closed up by the for-
mation of a clot of blood poured out at that spot, and
which thus entirely covers in the ovum The latter
now comes to he absolutely embedded in the wall of
the uterus in a cavity which it has itself formed. It
does not, however occupy the whole of the cavity, but
is surrounded by blood which is escaping from the
minute blood vessel of the wall in which the cavity
has been made This blood is of course, the maternal
blood   Thus we have the ovum completely embedded,
lying free in a tiny cavity in the mucous membrane
lining the uterus a cavity full of blood, in which the
ovum lies bathed, and from which it presumably
absorbs nourishment by osmosis through its tropho-
blast " (R W Johnstone)

The uterine wall after this embedding of the ovum
within it, undergoes a remarkable growth at this posi-
tion, concerning which a word must be said. Under
normal conditions this wall is smooth, or nearly so,
but probably there are upon it some slight irregularities
or projections which are sufficient to catch the ovum
when it enters the uterine cavity Apparently it may
be arrested in this way at any part of the wall, and it

that spot it becomes embedded in the manner we have described above. The lining membrane of the uterus under ordinary conditions measures about one-eighth of an inch in thickness, but, after the ovum has become embedded in it, it begins to increase until it reaches as much as half an inch. Underneath this lining membrane lies the muscular part of the uterine wall. The ovum itself is embedded about the middle depth of the lining membrane, but as it continues to grow, and increases in size and dimensions it projects more and more into the uterine cavity, that being the direction of least resistance. Before very long the embryo as it now is, has reached such a size in its growth that it entirely fills the cavity of the uterus. This stage is reached after the third month of gestation

Another structure, concerning which just a word must be said, is that known as the " placenta," or more commonly as the " after-birth." We need only say that this is first developed by means of a number of little outgrowths by means of which the early embryo is attached to the wall of the cavity in which it lies. These outgrowths grow into the uterine tissue around the ovum, and they allow of blood circulating between them. They have, as a matter of fact, two distinct functions to perform— first, that of fixing the ovum in position, and, secondly, they allow of the maternal blood circulating in the spaces between them, and it is from this blood that the embryo derives its nourishment. The blood-vessels ultimately connect with those of the umbilicus, and thence reach the embryo. This organ, the placenta, at the time the embryo is fully developed at birth, is a round structure about nine inches across, and not quite an inch thick in its middle,

becoming thinner towards the edges. The surface of it next to the infant is smooth and shiny, beneath which it is rough, that next to the maternal structures being dark-coloured, somewhat like flesh. When the child is born, the severing of the umbilical cord allows the placenta to remain behind in the uterine cavity, whence it is usually expelled shortly afterwards. Should, however, this not be done, and the embryo and the placenta be born together, the child is said to be " born with a caul," an event which has given rise to many superstitions.

The foregoing description of the principal events in the development of the embryo will be sufficient for our purpose here. Further details on the subject would necessitate a considerable knowledge of physiology and anatomy, and those reader, who desire to study the details of the subject further may do so in any of the various works referred to in the bibliography appended to this book.

CHAPTER VII

THE BEGINNINGS OF THINGS

WE may next turn our attention to the developing embryo at a very early stage, and note from which parts of its growing cells the different structures are ultimately developed, remembering all the while that all the subsequent division into specialised tissues is the result of the inherent possibilities in one single fertilised germ-cell.

It will be remembered that, as the result of the subdivision of the fertilised germ-cell, we had the formation of three distinct layers of cells. These layers we saw were termed the germinal layers, and were named respectively the " ectoderm," the " entoderm," and the " mesoderm "—the last appearing between the two former. It is from these three germinal layers that all the subsequent structures of the body take their origin, and although we cannot attempt to follow out in detail the growth of all these special tissues, it will, nevertheless, be of interest to note, in the briefest possible way, from which portion of the embryo they subsequently arise. Some of these we may afterwards note in detail. The total result may be summarised by simply giving a list of the various tissues, and the corresponding embryonic layer from which they come. Thus:—

A. From the ectoderm arise the following structures :—

Epidermis or skin.

The hair.

Various glands.

The lens of the eye.

The whole nervous system.

The nerve parts of the sense organs.

The membrane of the mouth.

The enamel part of teeth.

The membrane of the nose.

The lower part of the bowel.

B. From the mesoderm arise the following structures .—

The connective tissues of the body.

The bones.

The teeth, except the enamel.

All the muscles.

All the blood vessels of the circulation.

All the vessels which carry lymph.

The membranes of the heart, lungs, and bowels.

The kidneys and their ducts.

The reproductive organs.

The blood itself.

The fat and the marrow.

C. From the third layer of the embryo, the entoderm, arises :—

The lining of the alimentary tract

The lining of the larynx.

The lining of the trachea and lungs.

The cells of the liver, the pancreas, the thyroid, and thymus.

The structure termed the notochord.

From the above brief summary we see that the component tissues and parts of the body can be divided into three groups, each of which originated in one of the three embryonic layers. Moreover, if these three groups be scrutinised a little more carefully, they will be seen to differ very markedly from each other in the structures and tissues which are derived from them. Thus the structures from the entoderm (see C) are practically either in the nature of glands, or the lining of the alimentary tract. Those tissues coming from the mesoderm (see B), on the other hand, comprise most of what may be termed the supporting tissues of the body, such as the bones and the muscles and ligaments, as well as the vessels which constitute the great circulation of the blood and lymph. But perhaps the most remarkable of all is the list of structures which take their origin from the ectoderm of the embryo (see A). In this list will be found the most important structures in the whole human body, as well as some of those which are apparently of far less serious importance. It is rather surprising to find, for example, that the whole of the nervous system, including the brain and spinal cord, and the organs of special sensation, should be derived from the same layer of cells as gives rise to the very simple cells of the skin, which serve merely as a protective covering to the other tissues. It is curious also to observe that in addition to brain and skin, parts of the teeth also arise from this external layer. Evidently then this ectoderm or outer layer is of the very greatest importance in embryology, since from it arise all those parts of the embryo itself which are the most important in its future life.

CHAPTER VIII

THE BEGINNINGS OF THINGS (*continued*)

WE, have now considered, as far as is compatible with
the character of a work of this kind, the beginning
and development of the embryo taken as a whole, and
for the remaining part of our study of this subject we
may devote our attention to the beginnings of some
of the more important organs and functions in the new
individual. It will' be impossible to deal in detail
with all the important parts which ultimately consti-
tute the new personali'y, but a selection may be made
which will give some general idea of how great results
spring from very small beginnings. What will be
said here it may be hoped will be just sufficient to
stimulate the interest of those to whom the subject
appeals, and who may then turn their attention to
some of the larger works which go into greater detail
in this subject, a list of which will be found in the
bibliography at the end of this volume.

It must be remembered that quite a large number of
the characteristics that we usually associate with a
normal human being only come into existence, or at
any rate only become obvious, at some period longer
or shorter after birth. True, these characteristics
depend for their ultimate appearance upon the develop-
ment of the corresponding structures and organs in

the growing embryo, but in the case of some of these, those organs are not fully developed in embryonic life, and the manifestation of the functions associated with them may be delayed perhaps for years. This is notably the case, for example, with the reproductive organs which, though developed during the life of the embryo, remain functionless until the period of adolescence. The development of the human mind and intellect too, although depending, of course, upon the embryonic growth of the brain and the nervous system generally, is a matter of time and the environment subsequent to birth. It should be realised, however, in this connection, that the mind of the new individual, and all that is involved in that term, dates back ultimately, as regards its possibilities, to the moment at which the two germ-cells from the male and female respectively united in fertilisation. The adult mind develops from the mind of the infant. The infant mind appears as the result of the possibilities and the tendencies which were inherent in the germ-cells from which not merely the brain but the whole embryo sprang ; in other words, all that a single human mind connotes results from the possibilities in a single cell. Such a thought is a startling one indeed, and at first sight appears, perhaps, somewhat incredible. But a moment's careful attention to the problem will show at once that it is in reality no more wonderful than the fact that this single cell produces all the millions of other cells which in due time give rise to the skin, bone nerve, blood, and so forth, which make up the entire body of the embryo. The human mind, therefore—and indeed the human soul, if that term be used in any intelligible sense— takes its origin in the products of the multiplications

of germ-cells acted upon by their subsequent surroundings.[1]

With this passing reference to the fact that some important parts of an individual only grow to their full manifestations after embryonic life, we may pass to the consideration of the development of some of the more interesting parts of the embryo itself.

Amongst the most striking, and certainly the most interesting, of the various parts of the developing embryo, those which go to form the special senses are prominent. They are interesting not merely from their actual mode of growth, but especially also in connection with their evolutionary history. The study of how they have come into their present state in the higher animals leads us back to very small beginnings—indeed, to the time when there was no such thing as special sense organs for sight, hearing, smell and so forth, but where the organism had what may be termed a diffused tactual sense over and throughout the entire body. In the course of time this diffused general sense became specialised no better example of which could be quoted than that of the sense of sight, which was referred to, as many of our readers will doubtless remember, in Tyndall's famous Belfast address. He was referring to Herbert Spencer's theory of the manner in which vision was evolved. He pointed out that, as above noted in the lowest organisms sensation is a general thing diffused throughout the body, a kind of general tactual sense. As the result of environment, and gradual adaptation to external influences certain parts

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[1] The detailed study of this part of the subject is dealt with in the writer's work, *The Greatest Lif* (Duckworth, London), to which readers who are interested in this phase of the subject are referred.

of tho general surface of the organism became more responsive to these external stimuli than other parts. These areas, being those points at which sensation was most acutely felt, were nothing more or less than primitive sense organs. Thus in the progress of evolution the stimulus of the eye gradually became most pronounced in certain cells which contain pigment, these cells being more responsive to the light stimulus than the rest of the body. That was the beginning of an eye ; a group of cells more receptive, more easily influenced by light, than any other cells. In a slightly higher stage of evolution we find a special overgrowth of the skin which covers over the area in which these pigmented cells lie, obviously a protective measure on behalf of the specialised cells referred to. Then, still later, a lens is added, and the whole organ becomes more and more adapted to the necessities of the case, until it reaches the extraordinary perfection that is seen in the eye of such a bird as an eagle. On the same general principle, the other special senses also took their origin from this general diffused tactual sense, certain cells becoming specially adapted for receiving the stimulus of sound, others for taste, others for smell, and so forth.

CHAPTER IX

THE BEGINNINGS OF THINGS (*continued*)

IT is not necessary to describe in detail the beginnings of all the various structures which arise from that important layer of cells in the embryo which is termed the ectoderm ; but since it gives rise to that part of the embryo, which eminently places man in the first place in the world of animals, we may select it for a little further description. We may leave out of account the beginnings of the skin and the glands, and some other parts, and look for the moment at the origin of the nervous system, which includes the brain, the spinal cord, and the whole nervous mechanism of the individual. Since man's prominence depends upon the wonderful capacities in his nervous system, it is all the more interesting to note from what small and simple beginnings it has arisen.

As we have already seen, at a very early stage in the development of the embryo, a folding of its cells takes place, so that the upper embryonic area assumes the character of a groove. We may confine our attention to this groove for the moment, leaving out of account the other two layers of the embryo—namely, the mesoderm and the entoderm. It is this groove, which thus early makes its appearance, which is subsequently to play such a tremendous part in the for-

mation of the most important structures. It is called the "medullary groove." As growth proceeds and the cells continue to multiply and increase in numbers, the two edges or lips of the groove gradually approximate, and ultimately *fuse together. Obviously the effect of this is to transform what was the groove into a closed cavity or canal, which is therefore now termed the medullary canal. Arising in this simple manner, this equally simple structure is destined to become the central canal of the spinal cord, and the cavities in the brain, known as the ventricles. The walls of this canal, be it remembered, are composed of cells of the layer of ectoderm, and it is these cells which, as we saw, appeared very early in the development of the embryo that are now to proceed to develop into the brain, spinal cord, and, in fact, *the whole central nervous system. At first the cells appear all similar, but, as development goes on, they begin to differentiate themselves into different kinds, some forming the actual nervous cells of the brain and spinal cord, others developing into protective structures.

The hinder or posterior part of this medullary groove and canal is narrower than the anterior portion. This posterior narrower part is that which gives rise to the spinal cord. It very soon changes its character by the appearance of a number of constrictions at intervals running along its whole length. It becomes. as it is termed, segmented. A little later these successive segments are seen to correspond to the pairs of spinal nerves which arise from the cord. For the first part of embryonic life the developing spinal cord is of the same length as the canal, but as time goes on the canal grows longer than the cord. This involves the nerves

coming from the hinder portion growing longer than others. It is the front or anterior portion of this medullary canal which is concerned in the development of the brain itself, and here, at an early stage, two very obvious constrictions appear in the region of what is to be the brain, and these constrictions divide that brain area into three distinct parts, or vesicles. Part of the posterior vesicle ultimately develops into the *cerebellum*, or little brain. Another part forms the *medulla oblongata*, that important hind brain in which lie so many of the vital centres of nervous energy. The central cavity formed by these constrictions is of comparatively less importance, forming ultimately what is known as the *mid-brain*. The foremost or anterior vesicle, however, is of the very greatest importance, and its subsequent changes are more marked than either of the other two. From it is developed the great mass of the cerebrum itself, together with various outgrowths from it which have most important functions. Thus two of these outgrowths appear projecting from the lower part of the sides of the walls, and ultimately coming to reach the outer ectoderm. These two projections, or pouches, ultimately form the optic vesicle. Still later in development the whole of the anterior vesicle is again constricted, thus forming two distinct parts, the foremost of which, growing rapidly in two halves on either side of the middle line, ultimately give rise to the two cerebral hemispheres. These two cerebral hemispheres, therefore, arise, in the first place, as lateral enlargements of the anterior part of one of the primitive constrictions of the medullary canal. In their outer layers cells continue to make their appearance with great rapidity, and thus

OLFACTORY LOBE

CEREBRAL VESICLE

FORE-BRAIN CAVITY

HIND-BRAIN CAVITY

AUDITORY

SPINAL CANAL

OPTIC VESICLE

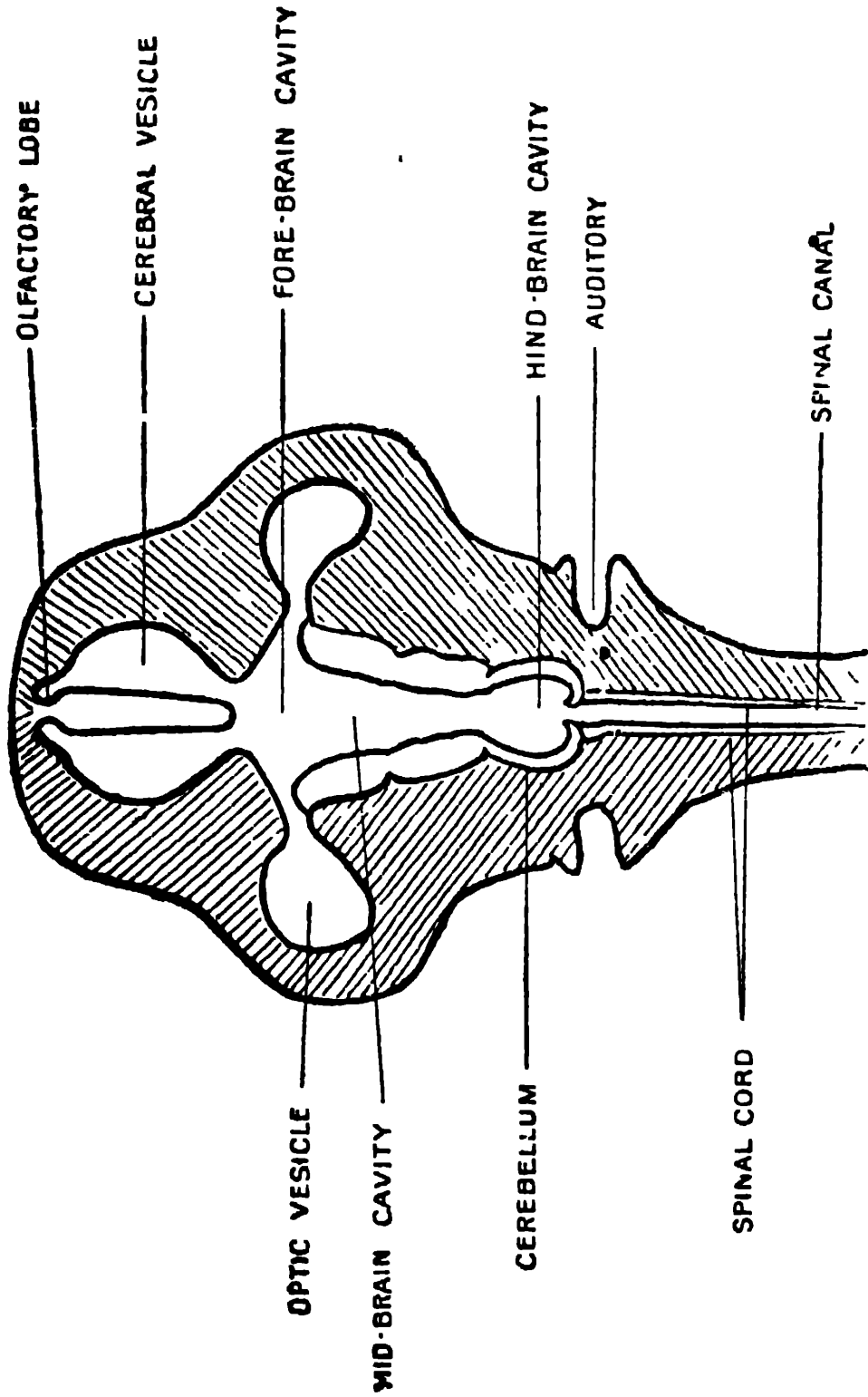MID-BRAIN CAVITY

CEREBELLUM

SPINAL CORD

FIG. 5.—Diagram of brain at an early stage, showing the origin of the olfactory lobe, the optic vesicle, the cerebellum, the cerebrum, the medulla, and the spinal cord (after Martin).

is formed the cerebral cortex; and the remarkable thing about this all-important part of the brain itself is that all the cells of this cerebral cortex appear to be produced during the life of the embryo; there being in all probability none · added after birth has occurred. That is to say, the possibilities of the actual physical growth of brain tissue in any given embryo are fixed from the beginning. Brain tissue, in other words, is born, not made. It is the manner in which it is treated afterwards upon which depends whether that given quantity of brain-cells displays its best potentialities or not.

We have seen that the optic structures are concerned with this front portion of the developing brain. The same is true of the organs which are concerned with the special sense of smell; for about the fourth week of the life of a human embryo there appears on the under surface of each of the cerebral hemispheres, towards the front, a prolongation which becomes the olfactory lobes.

It is well known that the surface of the brain of an adult human being, or, indeed, of any of the higher vertebrates, shows upon its surface a number of convolutions, and it is generally recognised, from a study of the comparison of different vertebrate brains, that the more convoluted is the surface of the adult brain the more highly developed is the animal concerned, from the point of view of brain power. The surface of the cerebral hemispheres, however, is quite smooth for some months of embryonic life, and the depressions which give rise to the appearance of the convolutions do not show themselves until about the fifth month, at which stage the brain is relatively large.

We referred on a previous page to the origin in evolution of visual sensation, and it may be of interest here to note a little more fully the beginnings of the eye itself in the embryo. As has been said, the very first appearance of these organs takes the form of a pair of outgrowths, or processes, which are hollow, from the front part of the anterior vesicle of the brain. These grow until they reach the ectoderm. A remarkable change then takes place. The portion of the hollow vesicle which reaches the outermost embryonic layer becomes folded in upon itself so as to form a cup with a double wall; just as one might form a cup in a blown-up paper bag by forcibly pressing one portion of it into the other. This double-walled cup is of special interest, because from its walls is ultimately developed that very important structure in connection with sight, namely, the retina. As soon as this is completed cells begin to grow from it towards the brain in the form of nerve fibres, and these in time convert what was originally a hollow process or growth into a solid mass of nerve tissue. This mass is the optic nerve. Thus is completed the connection between the outer surface of the eye and the brain itself, which is to receive the sensation. Then the ectoderm on the surface over the cup begins to thicken, grows into the cup itself, and ultimately forms a rounded hollow mass which we afterwards recognise as the *lens* of the eye. Still later this becomes separated from the surface by another layer of cells constituting the *cornea*, and outside that again is still another layer which makes the *conjunctiva*.

Subsequently the contents of this cup become filled up from other sources with a soft gelatinous tissue. Then the eyelids in time make their appearance in the

shape of folds of skin growing over the eye, and remaining in contact until very shortly before birth occurs. And so we see that from this wonderful layer of ectoderm there comes gradually into existence not only the brain itself and the spinal cord, with all the nerves, but also the special sense organs of sight and smell.

CHAPTER X

THE BEGINNINGS OF THINGS (*continued*)

WITHOUT entering into the description of the development of the whole circulatory system, we may just mention briefly the origin of the heart itself, which begins at a very early stage by the appearance of a small body of cells, which come to arrange themselves in a tubular form enclosed in the mesoderm. The two halves of this tube are at first quite separate from each other, but gradually come together and finally unite into a single tube with walls. The folds of these ultimately form the heart muscle. The organ, at this stage of its development, does not lie within the region of the chest cavity, as it afterwards does, but more anteriorly in the region of the neck. The simple tubular arrangement, however, is quite a passing phase, and as the tube increases in length it becomes bent upon itself, somewhat in the form of the letter S. One end of it now enlarges and forms a pouch on each side, these forming the two auricles, right and left. From these auricles a partition grows vertically, and when complete, cuts them off from each other, except that a communication is left in the upper part (*the foramen ovale*) which closes up after birth. This partition allows of the blood from one side of the heart passing to the other. Another partition eventually divides off that

portion which has formed the auricles from the remaining portion which develops into the ventricles, which in their turn become again divided by a still further partition. In this way the heart which, in the first place, was a simple tube, grows ultimately into an organ with four distinct chambers, two auricles and twŏ ventricles, the only difference from this and the adult heart being the communication which exists through the partition separating the two auricles.

The development of the organ of hearing is somewhat complicated. The first part to appear is a portion of the inner ear, which shows itself as a round, hollowing of the ectoderm. This depression becomes deeper and sinks further in, while its floor becomes thicker, and finally the whole assumes the shape of a closed cavity. An outgrowth from this gives rise to the *cochlea*. The cavity becomes divided into two portions, in one of which the *semicircular canals* arise. Around the whole, the embryonic tissue has been forming into a strong protective covering, some of which finally becomes cartilage, and some bone. The middle portion of the ear is the remains of a cleft in the side of the embryo. This cleft becomes changed into a canal by the closing of its edges, the upper part ultimately forming the *tympanic cavity*, and the rest of it remaining as the *Eustachian canal*. This canal opens into the pharynx. In the cavity there are subsequently developed three small bones which play an important part in the process of hearing. After the birth of the embryo, air reaches the tympanic cavity, which then enlarges. One of the walls of this cavity persists as the tympanic membrane or drum. Finally the outer ear, that portion which is popularly spoken of as *the* ear, is formed from

the upper portion of the same cleft which gave rise to the tube of the tympanum.

We have referred in the preceding description to the origin of some embryonic structures from a cleft in the early embryo itself. As a matter of fact no less than four of those clefts, or fissures, appear in the region of the neck on each side, and are of the very greatest interest and importance in connection with embryology. They are termed the " branchial clefts," and are seen in the embryos of all vertebrates. In the human embryo there are four. They are situated on each side of the pharynx, and they correspond to the gill slits in lower vertebrates.

Amongst other structures which arise from the important layer of ectoderm are the teeth. Of these there are during life two sets, a temporary and a permanent. The temporary teeth, though they do not make their appearance till after the birth of the embryo, still are partly developed during embryonic life, lying embedded in the tissues until the familiar process known as " cutting the teeth " takes place. This is, of course, merely the time of their external appearance. The first stage in the development, however, is a thickening of the epithelium of the gums in a direction which is to correspond with the line where the teeth will eventually pierce. This thickening is called the " dental ridge." This grows downwards into the underlying tissue in flask-shaped growths. From the neck of each of these flasks there is a small projection which indicates where the permanent teeth will ultimately be. This first stage is termed that of the *enamel germ*. This becomes surrounded by cells which ultimately form a *dental sac*. Next, tissue from below

grows into the flask, and the further growth of this gives rise to the *enamel organ*. Finally, enamel itself and dentine are developed, and the embryonic tooth remains covered under the gums until it cuts them.

So far we have considered merely the mode of development of the most important organs of the body, but we have said nothing of the most important supporting structure, namely, the skeleton. The earliest appearance of anything in the shape of a skeleton is the structure known as the notochord, a structure of immense importance and interest in the embryology of all vertebrate animals, in which it is a temporary thing only. The first appearance of this notochord in lower animals is the earliest indication of the vertebrate type, because it is found that in the higher vertebrates it is the forerunner of the bony spinal column and the skull. It appears first as a groove underneath the medullary groove, of which we have already spoken, and its two lips unite to form a cavity, as did those of the medullary groove. In this case, however, the groove becomes a solid rod, then termed the notochord, and it lies immediately under the medullary groove itself, which, as we have seen, gives rise to the central nervous system. In the course of development, masses of cells come to arrange themselves on each side of the notochord, which they eventually include, and at the same time they grow upwards and around the spinal cord which is thus enclosed. Later on these surrounding portions become cartilage, and, still later, bone ; the notochord meanwhile gradually disappearing where the bony spinal column appears. This primitive vertebrate structure therefore, of the notochord, has the all-important function of coming to

enclose, and thus protect, the spinal cord and nervous system.

As regards the other bones of the body, all that need be said here is that they are preceded by the structure which we know as cartilage, and in the bones of the limbs at two or three different points this cartilage begins to be transformed into bone. These points are known as centres of ossification.

CHAPTER XI

HOW THE EMBRYO IS NOURISHED

HAVING noted how the embryo itself takes its origin, and then studied something of the beginnings of some of its most important parts, we may now very briefly refer to the subject of its own nourishment. This has more than a mere academic interest, because obviously the proper growth and development of all the various tissues and structures in the embryo must depend ultimately upon the nourishment with which they are supplied. Their own inherent characters cause them to divide and subdivide so as to give rise to the millions of cells which are required to make the body, but these cells, in their turn, are dependent upon outside sources for the nourishment which enables them to keep on growing, or to maintain their full growth when they have arrived at that stage.

Nature has made many varied arrangements for this nutrition during embryonic life in different classes of animals. In some a considerable quantity of yolk is so arranged with reference to the embryo that the latter can draw upon it for some time for its supplies. This is the case, of course, in birds, and in some reptiles. We need here, however, only consider the case of the human embryo.

Three sets of structures are concerned in human embryonic nourishment, namely, the Allantois, the Villi of the Chorion, and the Placenta.

The Allantois is developed in the form of a hollow bud from the posterior part of the primitive alimentary canal, and ultimately comes to form the umbilical cord, and the embryonic part of the placenta. It is this structure, the allantois, which allows at a very early date of the embryo establishing a blood-connection with the maternal tissues, and hence it plays a very important part in the transmission of nourishment to the embryo. Not only does it do this, but it allows of the removal of waste products.

The villi of the chorion are outgrowths by means of which the very early embryo attaches itself to the walls of the cavity, which it has made for itself in the wall of the uterus. As they grow larger, these villi push their way into many of the small blood-vessels in the uterine wall, and so come to lie actually in a mass of blood from which they abstract the elements of nutrition. At first the villi themselves contain no blood-vessels. Nourishment passes through them by a simple process of osmosis. Later on, vessels grow into the villi themselves. The nutriment supply is secretion, in the first place, of the uterine glands, which these villi easily absorb. This process takes place during the first two or three months of embryonic life. At the end of this time most of the villi disappear, and the few that remain take part in forming the foetal or embryonic portion of the placenta.

After the third month the embryo is nourished by the placenta itself, which is at this stage developed.

As we have seen, it arises partly from the villi of the chorion, which is its embryonic portion. The other part of it is maternal in origin, arising from the portion of the uterine wall which is immediately over the embryo. The connection between this structure, the placenta and the embryo, is constituted by means of the umbilical cord. The function of the placenta is partly to supply nutrition, partly to serve as an organ of respiration for the embryo, whose lungs are, of course, not functional, and partly it acts in the same way as the kidney does in after life, by excreting certain products. From the placenta the embryo derives those food elements at first provided by the secretion of the uterine glands. Afterwards these elements are supplied by cells which lie between the fœtal villi and the blood of the mother. Its, respiratory function consists in allowing oxygen and carbonic acid gas to pass by osmosis between the embryonic and the maternal blood. The process is exactly analogous to that which takes place between the gills of a fish and the water in which the fish lies. Of course, it will be easily understood that there is as yet no great need for a large supply of oxygen, because the embryo is merely growing, and not using its various organs.

It should be clearly understood that under ordinary conditions of embryonic life there is no direct mixture of the blood of the mother and that of the developing embryo. All the processes which contribute to its growth and maintenance, including those of respiration and excretion, take place through the intermediate structures above mentioned. This is an extremely important point, because it means—and evidently that is the object of the arrangement—that there may be

much of an injurious character in the blood of the mother which never reaches the embryonic tissues at all. Doubtless the cells which form the organs of nutrition for the embryo have a capacity for selecting the elements required for purposes of nutrition. It is their business to look after this process. How perfectly it is performed can at once be understood when we recollect how very frequently the tissues of the mother herself are in anything but perfect health, and yet the embryo is born healthy. Were it not for this intermediary process, the embryo could hardly help being poisoned or otherwise injured by all the varied unhealthy products and substances which the ignorance of some mothers allows to be present in their blood during this important period. Even with this means of protection, the maternal blood may be so utterly deficient in nutritive qualities, or so actively injurious from saturation with alcohol, or from some equally toxic substance, that the fluids which reach the embryonic cells may be very much impaired in quality. Nevertheless, it is astonishing how much danger can be avoided in this way by Nature's provision in the method of nourishing the embryo.

If the development and growth of the embryo in a human being runs a perfectly normal and uninterrupted course, the following points could be observed at various stages. At the end of the fourth week in growth, the embryo is distinctly curved, so that the two ends—the head and the tail—are close together, the whole being about half an inch in length. Even at this very early stage, the canal which gives rise to the brain and spinal cord is closed in. The vesicles of the eye and the ear have both made their appear-

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ance, and the limbs are just beginning to show as
buds. The heart is quite obvious, and its division
into its four chambers is commencing. In another
four weeks the embryo has reached the size of one
inch, and the head is beginning to take on a shape
more resembling that associated with a human being.
The tail, on the other hand, has now disappeared.
The limbs have grown to the extent that both hands
and feet are starting growth, and in the region of the
head both the eyes and the ears, as well as the nose,
can be distinguished. Even at this stage, however,
the sex of the embryo cannot be made out. A month
later, at the end of the twelfth week, a considerable
development has taken place. The embryo is now
about three and a half inches long. There is a general
growth to be observed, and the bones are beginning
to ossify. In sixteen weeks, when the embryo measures
about five inches in length, the sex is easily distin-
guishable. The most characteristic thing for the weeks
succeeding this is the relatively large size of the head,
upon which hair appears at about the twenty-fourth
week. In twenty-eight weeks the embryo should weigh
about 2½ lb., that is to say at the seventh month of
embryonic life. Should the child be born at this time
as the result of any of the causes which give rise to
premature birth, there is a possibility that it may
live, though as a rule it does not. Four weeks later
it should weigh 3½ lb., and if born now may frequently
live, if carefully attended to. In another four weeks
the embryo is nearly eighteen inches long, and weighs
about 5½ lb., and the body has a more rounded appear-
ance, because by this time there has been a consider-
able growth in fat. If born at this stage it ought to

be quite possible to save the life. Finally, at the end of forty weeks, the normal full embryonic period of human life, the healthy child should weigh about 7 lb., having smooth, pink skin, and being otherwise perfectly developed.

CHAPTER XII

RECAPITULATION

IN bringing our study of Embryology to a close, we may glance briefly at another aspect of the subject, namely, that which emphasizes the fact that in its development the embryo recapitulates the history of its ancestors.

It is quite obvious that the offspring of any species of animal, if they are to live and survive in the same kind of environment as that in which their parents live, must resemble them somewhat closely. The only way in which Nature can secure such a sufficiently close resemblance of offspring to parents is by insuring that they should develop along similar lines. So it is that we find that the whole of the life history of an individual is more or less a recapitulation, with, of course, variations, of that of the parents and ancestors. Each successive step from the very beginning of the fertilisation of the ovum repeats a stage through which previous generations have passed. If from any accident a step in this recapitulation is omitted, the embryo is to that extent deprived of some feature possessed by a parent or ancestor; and if this be a sufficiently important omission, it is impossible for such an embryo to survive. That is one way in which an embryo may differ from its parents. That is a retrogressive change.

On the other hand, such an embryo, in addition to recapitulating the stages through which its parents passed in development, may have something new added, something which appears for the first time. In other words a progressive variation may appear.

Now, since the embryo follows the same developmental track as did the parent, passing through the successive stages of germ-cells, fertilised ovum, embryo, foetus, infant, child, youth, and adult, it follows that should it exhibit any additional peculiarity, unnoted in the parent, the embryo has obviously varied progressively. That is to say, it has pursued the same line of development together with some new addition. On the other hand, should the offspring at any of these stages in its career be obviously without some of the characters of previous generations, it is as certainly due to the fact that the recapitulation of the history of development has been, in that particular, incomplete.

In all successive cases of multicellular organisms, development by a process of repetition of what happened in the previous generation seems to be the rule ; and it would appear that only by this means could a mass of cells which constitute an individual grow into something sufficiently like the parents as to be recognised for their offspring Given the fact that a human individual starts from a single germ-cell, it could only be by following the same steps in development trodden by the parent that the new individual could attain a similar growth. The object of this similarity is, of course, to provide that the offspring may live and survive in an environment more or less similar to that of the parents. As Dr. Archdall Reid

puts it, " the embryo starting from the same point, must follow the same road to reach the same goal. The embryo which did not recapitulate the history of the development of a parent would be a monstrosity."

While, however, recapitulation in development is always more or less clear, it does not follow that it is perfectly complete, nor perfectly identical with the development of the parent. Indeed, on the other hand, there is always a certain amount of variation, either progressive or retrogressive. Progressive variation means that in addition to the development of all the parental stages, something new has been added. Retrogressive variation means that from the total development experienced by the parent, something has been omitted. We are here speaking of characters of a species, and it must not be thought that we are referring to the characters of the embryo as if they were derived from those of their parents. This was clearly pointed out in the earlier portion of our study. The variations in development, to which we here refer, take their origin in the germ-plasm which tends to repeat in each generation similar types of development. In other words the germ-plasm from which individuals spring is of such a nature that the embryos arising from it show in their development a recapitulation of the evolution of their particular species. In addition they may show variations of either a plus or a minus character. These variations are frequently inherited, and persist throughout succeeding generations. In course of time, if there are many of such variations, they accumulate, and to that extent, of course, alter the life history. That is why in watching the develop-

ment of a human embryo it is impossible to trace accurately the early ancestral development of the race from it. It passes through the stage of a single cell, then becomes multicellular, and gradually assumes the form of a higher and higher type of organism. ." Manifestly the additions and subtractions have been vast. It possesses, for instance, a placenta,, an organ by which it is attached to the mother, through which it is nourished, and which at one time is larger than the embryo itself; but which, of course, could not have been present in its prototypes. Nevertheless the life history unfolded by the child is just as real, just as complete, and probably more accurate than any written chronicle that attempts to describe the whole past of a race." (Reid.)

> " There is a history in all men's lives
> Figuring the nature of the times deceased."

Here we must conclude this brief sketch of some of the principal facts in the science of Embryology, in the hope that enough has been said to stimulate the interest of our readers in this subject to such an extent that they may be encouraged to pursue its study still further in one of the many text-books that are devoted entirely, or partly, to this matter.

We would urge in conclusion that the study is well worth while, even for those to whom it has a non-professional interest. It should be sufficiently obvious to any earnest thinker that the problems which are involved in the study of embryology are precisely those which are of the very greatest importance to humanity at large. With this subject is most inti-

mately bound up that of heredity itself, which has been dealt with in another volume of this series. No true understanding of what can be done, or what should be done, in the direction of improving the lot of generations to come, or of making the most of the generation at present existent, can be obtained by any who are absolutely ignorant of these topics. It is only by their study that we realise that the human embryo, which is to become the human individual, consists, to a very large extent, of characters and features which are unalterably settled for it before-hand, to which nothing can be added, and from which nothing can be taken away. In other words, the possibilities for any individual are those which are pre-existent in the germ-plasm from which he or she originates. These possibilities, however, depend upon the environment in which the embryo, infant child, and adult is subsequently placed for their full expansion. In many directions the inherited tendencies transmitted by the continuity of germ-plasm are un-alterably and strictly defined. In many other directions these inherited tendencies can be so modified, drawn out, or even partially suppressed, by suitable surroundings of a hygienic, educative, and moral nature, that if the process be taken in hand sufficiently early wonderful successes may result. These results are those for which the social reformer and the philan-thropist and the serious studet of sociology are earnestly striving, but it is only by a study of the sciences of Heredity and Embryology that accurate data can be obtained from which justifiable conclusions may be drawn.

The great fact which embryology teaches is that the

past is unfolded stage by stage, with certain omissions and additions, so that in very truth—

> " The softest dimple in a baby's smile
>   Springs from the whole of past eternity,
>   Taxed all the sum of things to b. ᵢ ., ᵢ, ᵢ ᵢ there."