CHAPTER XIX

EMBRYOLOGY

Introduction. As human beings, born with the deep-seated urge for self-preservation, we regard the individual as of supreme importance. The various physiological activities comprising metabolism and adjustment are sufficient of themselves to secure the welfare of the individual. And yet there remains the function of reproduction exhibited by all animals and plants. What is the meaning of this? As far as the individual is concerned, the exercise of this function is unnecessary for the maintenance of life. We must look beyond the individual for the answer. The function of reproduction present in individuals secures the continuance of the species. If we regard the individual in respect to metabolism and adjustment as an active physico-chemical organization *sui generis*, we must also regard it as *supremely unique* in its ability to insure the continuance of that organization by the exercise of the function of reproduction.

Biogenesis. In the seventeenth century, William Harvey (Fig. 293), the discoverer of the circulation of the blood, studied the embryonic development of the chicken from

Fig. 293. — William Harvey, discoverer of circulation of the blood. From Locy: *Biology and Its Makers.* Courtesy Henry Holt & Co.

the egg and believed that he had discovered a universal law of biology, namely, that "all life comes from the egg." But the examples of reproduction by fission, budding, parthenogenesis and spores demonstrates that Harvey's statement must be modified.
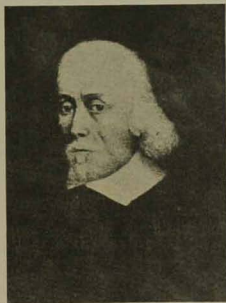
It *was* modified many years later to " all living things come from living things."

But this law of *Biogenesis* was not established until about 1876. Prior to that time it was generally believed that many organisms originated from non-living matter by " spontaneous generation," as it was called, and this is the theory of *Abiogenesis*. It was very natural for Aristotle, in the third century, B.C., to conc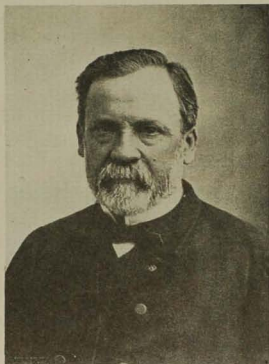lude that insects and frogs arose from mud. Bees, flies, mice and rats were for a long time supposed to have originated in this way. Even Alexander Ross, in the eighteenth century, sarcastically wrote that " to question this, is to question reason, sense and experience." In every age, some *authorities* make dogmatic assertions which are without basis in experience.

In 1668, Francesco Redi, an Italian, tested experimentally one of these imagined cases of spontaneous generation. He placed meat in several jars, some of which he left open, and covered others, some with wire gauze and some with parchment paper. The meat in all the jars decayed. Maggots (fly larvae) and, in time, flies appeared in the *open* jars. Neither maggots nor flies appeared in the *parchment-covered* jars. This showed that when flies could not get to the meat, there was no spontaneous generation. Flies lay eggs in decaying meat, and the eggs develop into flies. Flies come from flies. Other workers verified these results. Toward the end of the seventeenth century the compound microscope appeared and, with the aid of it, a new world of microorganisms was discovered, such as minute Algae and Protozoa. In 1687, the Dutchman, Leeuwenhoek, discovered Bacteria. It was now asserted that the origin of living things was from minute organisms, which had arisen spontaneously. This idea per-

FIG. 294. — Louis Pasteur, great bacteriologist.

sisted until the latter part of the nineteenth century. The methods of reproduction and life history of these forms were gradually ascertained and it was learned that dust, air and, in fact, all things contain spores of such organisms. These can *seed* any organic material left exposed to air, and the existence of hosts of such organisms is due to reproduction from parent organisms. Pasteur (Fig. 294) in 1860–64, by a series of most painstaking experiments, demonstrated the presence of microorganisms in air and on dishes. He also showed that some of these organisms (*anaerobic*) did not need free oxygen, but could get it by their own ability to decompose organic substances. His experiments constituted important disproof of Spontaneous Generation.

John Tyndall, the great English physicist, worked on optically pure air some time after this. He believed that such air, which contained no particles of any kind, would therefore, contain no microorganisms, and that if organic materials, which had been heated to such a temperature as to destroy all adhering living organisms, were exposed to such air, that then no life would appear in them. Tyndall's experiments, published in 1876, were convincing. It was proved that there was no spontaneous generation of life, and the age-long question was settled and today it is believed, as a general biological law, that so far as we know all living things come from living things.

But this does not imply that life has always existed. If the astronomer's hypothesis is correct that this globe was once a gaseous outcropping from the sun, no form of life known today could have then existed. It has been suggested, however, that life units could have come to the newly cooled earth from some other planet. However, it is not known that life exists on other planets nor does this explain the ultimate origin of life.

The chemist knows that water is a union of hydrogen and oxygen. Water has not always existed. It was *created* when hydrogen and oxygen united to form it. Neither hydrogen nor oxygen has the properties of water. Water is a thing by itself. Moreover, it is now believed on good evidence that not even the present elements, as we know them, have always existed, but that they have originated from preceding simpler things. So it is legitimate to suggest that living substance came into existence when the Earth was cooling — when there was atmosphere and water and when certain compounds of carbon, oxygen, hydrogen,

nitrogen and sulphur, etc., were brought together in a certain way. Just as oxygen and hydrogen existed (as in the sun today) before water, and as water is something new and not at all the same as oxygen and hydrogen, so living substance is not merely oxygen-hydrogen-carbon and nitrogen, even if these existed prior to the formation of living substance. Life is a peculiar phenomenon in itself and protoplasm is the unique medium in which it finds expression. All notions as to the primal origin of life are speculations. That protoplasm arose spontaneously long ago is good speculation.

Germ Plasm and Somatoplasm. As a rule, animals reproducing sexually begin life as a single cell, the zygote, formed by the union of a spermatozoon and an egg produced respectively by a

male and a female animal. Sperm are formed by a special gland or gonad called the testis and eggs by another type of gonad, the ovary. The tissues and organs of metabolism and adjustment cannot produce gametes. The protoplasm of gametes is unique in that the zygote cell formed by the union of a male and female gamete can form a new individual. None of the other specialized cells possesses this property.

Facts such as these led Weismann (Fig. 295) to develop a theory set forth in his book entitled "The Germ Plasm," published in 1885. Some of the conclusions he maintains are these, although the evidence cited in support was not necessarily given by him: First: The protoplasm of gametes and of gamete-forming cells of gonads is different from that of other cells of the body, being denoted by the name *germ plasm* for the former and *somatoplasm* for the tissue cells. Second: Early in development (Fig. 296) germ plasm tissue is set apart from the body tissue or somatoplasm. Third: Somatic tissue may be modified by varying external and internal stimuli, but germ plasm remains unchanged throughout changes in environment; a great body of evidence supports this view. Fourth: Although Protozoa possess physical immortality because they reproduce by fission, which results in unbroken continuity of protoplasm from

generation to generation; yet the greater part of the body (somato-plasm) of a metazoan animal dies at the end of life's span while its germ plasm is immortal, *i.e.*, continues life in the person of the offspring. Among the Metazoa, germ plasm is the living bridge which ever continues from generation to generation. Fifth: The germ plasm of the egg is not exactly like that of the sperm and neither are entirely representative of the individuals which produced them, so that *fertilization, in forming a zygote, effects a new combination of characteristics not hitherto existing.* The union of different protoplasms in fertilization is called *amphimixis. The effect of sexual reproduction is to bring about variation.* The cytological details of germ-cell formation and observations in breeding experiments support this conclusion. Asexual reproduction, on the other hand, effects the continuance of the same type of protoplasmic complex. If a form produced by asexual reproduction differs from its parent, the cause of the variation must be sought for in a different set of environmental conditions to which the offspring was subjected.

Fig. 296.— Four-cell stage in development of Ascaris. The cell marked 'G' will develop the germ-cell forming tissue while the rest of the body will be formed from the other three cells. From Conklin (after Boveri): *Heredity and Environment*, Princeton University Press. Reprinted by permission.

Germ-Cell Formation. The development of germ cells from gonads has been studied cytologically and these studies reveal many different kinds of changes, many of which concern the chromosomes. The student will be aided in understanding the processes of germ-cell formation if it is kept in mind that studies in the allied field of genetics indicate that chromosomes are made up chiefly of many ultramicroscopic multimolecular bodies called *genes*, probably protein in composition. Each gene is a determiner of a special characteristic that will appear in the developed individual. If, as stated above, germ-cell formation involves chiefly distribution of chromosomes and if the latter are composed of genes, it follows therefore that germ-cell formation is vitally related to problems of heredity.

The cytological changes involved in the production of spermatozoa from undifferentiated cells in the testis are denoted by the
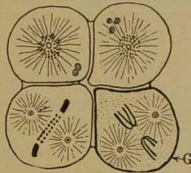
term *spermatogenesis*. The changes taking place in the production of ova from an ovary are denoted by the term *oogenesis*. These will be considered separately.

Diploid and Haploid Chromosome Numbers. Every individual is in a sense a duality. We already know that every cell in the body contains chromosomes. These, however, occur in pairs. Human body cells contain 48 individual chromosomes, *i.e.*, 24 pairs. As a rule, each pair of chromosomes has a distinct size and form, but both members of any one pair are similar in form (Fig. 297). One member of each pair was descended from a similar chromosome of the spermatozoan, and its mate in the same pair from a like chromosome in the ovum, when the individual was only a zygote, *i.e.*, a newly fer-

FIG. 297. — The four pairs of chromosomes of Drosophila (after Bridges). From Morgan: *Critique of the Theory of Evolution.* Princeton University Press. Reprinted by permission.

tilized egg. Let us say that a sperm containing chromosomes *a, b, c* fertilized an egg containing chromosomes *a′, b′* and *c′*. The zygote contains chromosomes *a, a′*; *b, b′*; *c, c′*. By a series of mitoses, in development the zygote becomes a sexually mature individual, every one of whose cells contain chromosomes *a, a′*; *b, b′*; *c, c′*. Each of these chromosomes is divided at every cell division in the life of the animal into two daughter chromosomes and daughter cells will always contain a similar set of chromosomes, *a, a′*; *b, b′*; *c, c′*. But as indicated above, this individual was derived from two sex cells, one contributing chro-
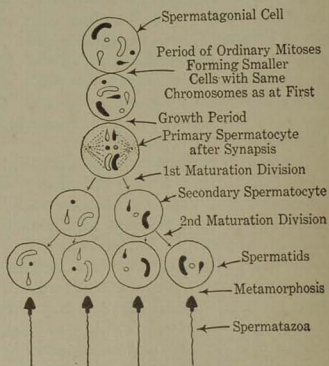
Spermatogonial Cell

Period of Ordinary Mitoses Forming Smaller Cells with Same Chromosomes as at First

Growth Period

Primary Spermatocyte after Synapsis

1st Maturation Division

Secondary Spermatocyte

2nd Maturation Division

Spermatids

Metamorphosis

Spermatazoa

FIG. 298 A. — Diagram illustrating spermatogenesis. Compare with Figure 298 B.

mosomes a, b, c and the other a', b', c'. We say that the cells of the body contain a *diploid* number of chromosomes and the sex cells the *haploid* number.

Spermatogenesis (Figs. 298 A and B). Let us ascertain how sperm are formed. Each spermatogonial or primary testis cell contains, for example, chromosomes a, a'; b, b'; c, c'. These cells undergo rapidly a series of mitoses, forming small cells each of which will also exhibit chromosomes a, a'; b, b'; c, c', each time a mitotic spindle is formed. After this *period* of *rapid multiplication*, the cells stop dividing and undergo a *period* of *growth;* that is, they increase in size, forming *primary spermatocytes,* in which a mitotic spindle is later formed. In this, the chromosomes have united or paired off thus: a-a'; b-b'; c-c'; homologous chromosomes have lined up alongside each other.[1] If we regard a, b, c as *male* in the sense of being derived by descent from the male parent, and a', b', c' as female
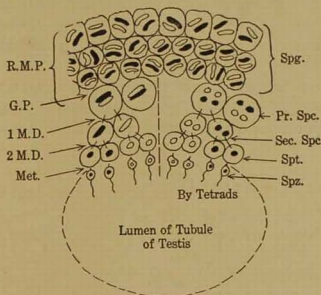

FIG. 298 B. — In this diagram a segment of a tubule of the testis is indicated. Outer row of cells are spermatogonia, *i.e.,* primordial germ cells. On the left are indicated: R. M. P., Period of rapid multiplication; G. P., Growth period; 1 M. D., 1st Maturation division; 2 M. D., 2nd Maturation division; Met., Metamorphosis. On the right are indicated: Spg., Spermatogonia; Pr. Spc., Primary spermatocytes; Sec. Spc., Secondary spermatocytes; Spt., Spermatids; Spz., Spermatozoa. Sometimes in synapsis, the double chromosomes appear in fours, *i.e.,* as *tetrads,* as shown at right of dotted line.

in a similar sense, then in the above pairing off, similar male and female members of the pairs associate in this union called *synapsis.* Synapsis is the first step in the final processes of maturation stages of spermatogenesis. After synapsis, the first maturation mitotic division occurs. When the two daughter cells called *secondary spermatocytes* are formed, each receives one member of each pair of chromosomes. For example, if one cell receives a, b, c, the other must receive a', b', c'. A second possibility is that one cell

[1] See Allelomorphs, Chapter XXIV.

receives *a, b, c'* and the other *a', b', c*. Eight different possible combinations are shown in Fig. 299. Immediately after the first maturation division, there follows the second maturation division, in which the chromosomes of the secondary spermatocytes are divided as in ordinary mitosis, each forming two cells (four in all) called spermatids. If one secondary spermatocyte possessed chromosomes *a, b, c*, then each of its two spermatids will possess chromosomes *a, b, c*. Similarly, the other secondary spermatocyte (*a', b', c'*) will form two spermatids each containing chromosomes *a', b', c'* or the four spermatids will have the following chromosome formula: 1. *a-b-c*; 2. *a-b-c*; 3. *a'-b'-c'*; 4. *a', b', c'*. So far the cells resemble the original spermatogonial cells in shape. But now the spermatids undergo a process of *metamorphosis* in which polygonal-shaped spermatid cells become modified
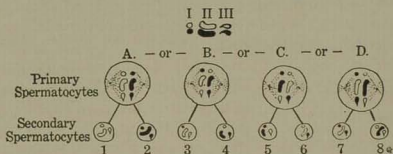

Fig. 299. — Illustrating eight different combinations of chromosome distribution when the primordial germ cells have three pairs of chromosomes.

into *spermatozoa*, each with a head, middle piece and tail (Fig. 302). The head is almost entirely concentrated nucleus surrounded by a thin film of cytoplasm. Indeed, the head is principally chromosomes *a-b-c*, for example. The middle piece contains a small amount of cytoplasm containing a centrosome in some cases. The tail is a long, vibratile, cytoplasmic thread. The motile sperm are liberated into the lumen of the gland ducts. Two things of importance are to be noted : First : As a result of spermatogenesis, sperm contain only half the number of chromosomes characteristic of the species, *i.e.*, the diploid number has been reduced to the haploid number and the reduction occurred in the first maturation division. In some cases the first division is an ordinary mitosis and the second is the reduction.   Second : Different kinds of sperm are formed.   In this particular instance, one is represented by the letters *a, b, c* and another by *a', b', c'*. But there might have been other types (Fig. 299), all depending on how they lined up in the equatorial

place of the mitotic spindle of the first maturation division. Possible variations are represented : a, b, c; a', b, c; a, b', c; a, b, c'; a', b', c; a, b', c'; a', b, c'; a', b', c'.

Oogenesis (Figs. 300 A and B). Development of ova from the ovary is fundamentally similar to that of the sperm, but it will be evident that growth is greater in the case of the oocyte than in the formation of spermatocytes.

There is a period of rapid multiplication of oogonia, resulting in the formation of *primary oocytes*. When the mitotic spindle for the first

Fig. 300 A. — Illustrating oogenesis. Compare with Fig. 300 B.

maturation division is formed, homologous chromosomes which were hitherto separated in all previous mitoses have now paired off in *synapsis*, making *half* as many *pairs* as there were single chromosomes. If the (diploid) chromosomes of the oogonia (and all other body cells) were a'', b'', c'', a''', b''', c''', then at synapsis they would be arranged thus : a''-a'''; b''-b'''; c''-c'''. The first maturation division (reduction) forms two cells. If one has received chromosomes a'', b'', c'', then the other must receive a''', b''', c'''. But as in the case of spermatogenesis there are other possible distributions, depending on how the synaptic pairs were arranged in the equatorial plane. For example, the distribution might have been a'', b''', c'' and a''', b'', c'''. The two cells formed are called *secondary oocytes*. These are not similar in size as are the secondary spermatocytes. One of the oocytes is *very small* although the nuclei of both are
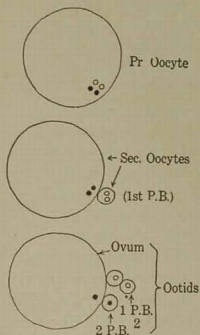

Fig. 300 B. — Oogenesis. In this diagram the size relations of polar bodies to ovum are indicated. The polar bodies are actually very much smaller.

similar and contain the same number of chromosomes. The *small* secondary oocyte with a minimum of cytoplasm is called the *first polar body*.

In the second maturation division, the first polar body (the *small* secondary oocyte) forms *two* very small polar bodies while the *large* secondary oocyte also divides into two cells, one of which is about as large as before, while the other is a *third* very small *polar body*. All four cells are called *ootids*. Only *one* is *large; the other three* are *very small polar bodies*. The large ootid is the functional *egg*. The polar bodies *degenerate*. It is important to note the chromosome distribution. If the large secondary oocyte contains chromosomes a'', b'', c'', then the first polar body contains a''', b''', c'''; the two polar bodies formed from the latter will each contain similar chromosomes. But all the polar bodies degenerate and if, as stated above, their chromosomes contain potential hereditary qualities different in some respects from a'', b'', c'', which the functional egg possesses, all the potential hereditary qualities peculiar to a''', b''', c''' will have been lost so far as this particular egg is concerned.

Chromosomes of Male Parent

a	c'
b	b
c	a'

Only a few of Many Possible Combinations are Illustrated

Chromosomes of Female Parent

b"	
c"	c'"
a"	a'"

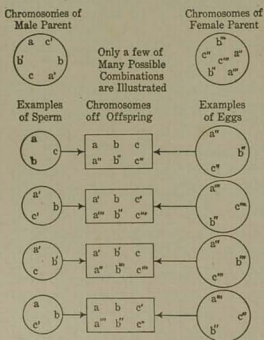Examples of Sperm   Chromosomes off Offspring   Examples of Eggs

FIG. 301. — Illustrating some of the different chromosome combinations in offspring of the same parents. The reader can discover other combinations. Compare with Fig. 299.

Oogonia, spermatogonia and all somatic cells of an individual possess a diploid number of chromosomes. One member of each pair of chromosomes of these cells was derived from the spermatozoan which fertilized the egg and formed the zygote, from which that individual developed. The other halves of each pair of chromosomes of the zygote were derived from the mother, *i.e.*, from the egg fertilized by that sperm. During all the thousands of mitoses occurring in development and during later life of this individual, these maternal and paternal chromosomes retain their original identity. During spermatogenesis and oogenesis, they pair off and one member of each pair is distributed to different germ

cells. This results in a reduction of the diploid number to the haploid number and also brings about the probability of a new combination of chromosomes in the succeeding fertilization. In the accompanying chart, Fig. 301, a few illustrations are given to illustrate how this can happen. Neither spermatozoan nor egg contains *all* the hereditary material of their respective originators. It appears that the function of *sexual* reproduction is to produce individuals *different* in some respects from their parents. The new individual *may be* better adapted to life conditions than were the parents. Sexual reproduction by sperm and egg, produced by spermatogenesis and oogenesis, accounts in part for variations in plants and animals. Not all details of spermatogenesis and oogenesis are identical with the type illustrated above, but the end results are similar.[1]

Egg and Sperm. The egg cell is highly specialized. It contains the machinery for cell division; from it many differentiated cells will form in development; it will develop a specific organism, *i.e.*, a starfish egg will produce a starfish, a frog's egg will produce a frog and each of a particular species. Most eggs contain a substance which when oxidized furnishes the energy for the early stages in development. The various kinds of eggs with regard to distribution of yolk and relative quantities of yolk will be presently considered. Compared with the sperm, the egg is large, passive and yolk-burdened.

Although there are many varieties, a *typical* sperm (Fig. 302) has three parts : (*a*) Head — this contains but little cytoplasm, it is almost all nucleus, *i.e.*, compact chromatin. (*b*) A middle piece, supposed to contain a centrosome. (*c*) A long undulating cytoplasmic tail, a locomotor organ. The sperm resembles a flagellate protozoan. Both sperm and egg agree in the possession of a chromosome equipment and the chromosomes of the sperm are in a sense mates of those of the egg.

a. Head - Nuclear Material, i.e. Chromatin

b. Middle Piece (Centrosome and Mitochondria)

c. Tail - Organ of Locomotion (Cytoplasm)

Fig. 302. — Diagram of a human spermatozoan. It is 50–60 μ long. From Jordan (after Meves), *Textbook of Histology*, copyright 1927, by D. Appleton & Co. Reprinted by permission.

[1] In plants, the cells of the sporophyte have the *diploid* chromosome number. Reduction takes place in the first division in the spore mother cell so that spores (pollen grains and embryo sacs) gametes and the cells of gametophytes have the *haploid* number.
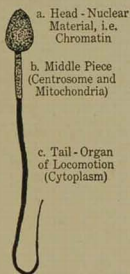
Fertilization. If sperm and eggs are deposited in water near each other, fertilization will occur there. If copulation takes place, then the spermatic fluid produced by the male reproductive system serves as the liquid medium in which the sperm may move toward the eggs. Sperm may enter the egg before oogenesis is complete or afterward. If the egg has a thin membrane, a sperm may perforate it and enter. A fertilization membrane, then formed, usually prevents the entrance of other sperm. In some cases the sperm is drawn into the egg from its surface. Only the head and middle piece of the sperm usually enter the egg.

Sperm contain only a limited amount of energy, but sufficient to bring them into contact with the egg. Fertilization does not occur in strongly acid or alkaline media. Activity of sperm takes place in the hydrogen-ion concentration of sea water or in water slightly more alkaline. Sperm are probably chemically attracted towards eggs. The physico-chemical system of the egg is somewhat analogous to a wound-up clock which is not going. Some substance in the egg inhibits the " starting up " of developmental processes. Something in the sperm overcomes this inhibition. It is said that anything that will cause the formation of an egg membrane will induce cell-division. F. R. Lillie's studies led him to conclude that the egg is an irritable physico-chemical system containing a definite substance called fertilizin, which, when free to act, starts up the machinery of development. The sperm has some substance which combines with fertilizin, overcoming its inertia and thus releasing it in an active condition.

When the sperm nucleus enters the egg, it is small but absorbs from the surrounding medium and increases in size. It moves toward the egg nucleus which, in turn, may move toward the sperm nucleus. The two appear to fuse, forming one nucleus, the zygote nucleus. The first cleavage is in the plane of the copulation path taken by the sperm nucleus in approaching the egg nucleus. It has been shown that, in many cases, the middle piece of the sperm contains a centrosome which will move ahead of the sperm nucleus and organize the first mitotic spindle initiating the first cleavage. In other cases this centrosome is formed in the egg and stimulated by the presence of the sperm nucleus. In the equatorial plane of this mitotic spindle appear the paternal chromosomes, introduced with the sperm, for example, " a, b, c," *and* the maternal chromosomes of the egg, i.e., " a'', b'', c''." These

will divide *individually* every time cell division occurs, but they do not *pair off* or undergo synapsis and later segregate to separate cells until the mitotic spindle of the first maturation division is formed at the time when this zygote has become a sexually mature individual. Note that the haploid number of chromosomes, characteristic of sex cells, is restored on fertilization to the diploid number which zygotes and their resulting cells possess.

Differences in Eggs as to Yolk Content. The presence and distribution of yolk varies greatly. In some eggs, there is a minimum of yolk and the cytoplasm is quite evenly distributed throughout. Most Coelenterates, Echinoderms, some Mollusks, Annelids, Amphioxus and the higher Mammals have eggs of this type.

In other eggs there is a greater accumulation of yolk at one end and it thins out toward the other end which is richer in cytoplasm. Two types are distinguished. In eggs like those of the frog, for example, there is no sharp line of demarcation between the cytoplasm and yolk, but they grade into one another. But in other eggs, like those of fishes, reptiles and birds, the egg cytoplasm containing the nucleus is in the form of a small disc-like mass at one end, sharply marked off from the great mass of yolk toward the other end.

Cleavage. The fertilized egg or zygote at once divides into two cells, thus initiating cleavage. Growth, differentiation and development of tissues and organs involve cell division by mitosis.

Fig. 303. — Cleavage in an Equal Holoblastic Egg. One, two, four, eight, sixteen and the thirty two cell stages are indicated.

But the word cleavage refers to early stage of cell formation in which the cells are increasing in number. The first cleavage plane passes through the *copulation path* taken by the sperm and egg nuclei as they unite in fertilization. In many cases it appears that the first cleavage plane establishes bilateral symmetry, *i.e.*, one of the first two cells forms the right side of the body and the other, the left side. Moreover it also appears the head will form from one end of these
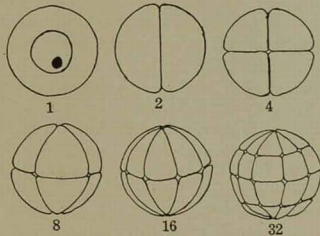
cells and the posterior part of the body from the posterior portion of
the two cells. The egg divides (Fig. 303) into 2, 4, 8, 16, 32, etc., cells
which become smaller and smaller as there is no absorption of material
from without. The presence of yolk modifies the type of cleavage.

Types of Cleavage. Four chief types of cleavage are found
among animal eggs.

A. Holoblastic. In this type of cleavage, the *entire egg* is di-
vided into cells. But there are two types:

1. *Equal Holoblastic* (Fig. 304 A). In eggs, with little and
diffuse yolk, as those of the star-fish and Amphioxus, the first
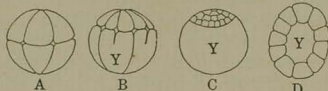
cleavage plane takes
place as indicated in
the preceding para-
graph and bisects the
egg (Fig. 303–2). The
second cleavage plane
is at right angles to the
first, and is also me-
ridional, forming four

Fig. 304. — Types of cleavage. *A*, Equal Holo-
blastic — starfish; *B*, Unequal Holoblastic — frog;
C, Discoidal Meroblastic — chick; *D*, Superficial
Meroblastic — insect. (*Y*, yolk).

equal cells (Fig. 303–4). The third plane is equatorial, forming
eight cells (Fig. 303–8). The fourth and fifth cleavage planes are
meridional and are in between the first and second and at right
angles to each other (Fig. 303–16). This makes eight cells above
and eight below the third plane. The sixth plane is parallel to
the third and between it and the upper pole, making sixteen cells
above. Almost at the same time, the seventh plane comes in
between the lower pole and the equatorial plane and parallel to it
(Fig. 303–32). This makes sixteen cells below or thirty-two in all.
Cleavage planes rapidly succeed each other now and the geometric
regularity is gradually lost. All the cells are of about the same
size and so this type of cleavage is called Equal Holoblastic.

2. *Unequal Holoblastic* (Fig. 304 B). Such an egg divides com-
pletely, but the resulting cells are unequal in size. At the time
when the first equatorial plane forms, there are four small cells
above and four larger cells below. Then eight cells are formed at
the animal or cytoplasmic pole above, before the larger four lower
yolk laden cells have divided. The greater amount of yolk here
seems to delay segmentation. This type of division is found in
some Sponges, some Coëlenterates, some worms, Mollusks, in
Petromyzon, some Fishes and in Amphibia.

B.   Meroblastic or Incomplete Cleavage.   In this type of cleavage, the yolk does not divide, but only the protoplasm.   Two types are recognized as indicated by Fig. 304–C and D.

It is evident that no particular type of cleavage is related to the degree of specialization of the type of animal.   It is more related to conditions under which development occurs.   A mature adult results despite the differences in mode of cleavage.   Very early in development and long before maturity the starfish and Amphioxus embryos become free-swimming and food-gathering.   In those cases where much yolk is present, the simple type of cleavage becomes complex.   In higher Mammals where placental feeding is resorted to, practically no yolk is needed.   The early cleavage stages are very simple, but soon depart from this on account of the highly specialized structures that have to be developed in connection with embryonic nutrition.

In the following description of later developmental stages, only simple illustrations will be chosen.   The student should be informed, however, that many embryological histories are far more complicated than these simple examples may appear to imply.   Nevertheless, in spite of the differences in development, there is an underlying similarity making possible the science of embryology.

Morula and Blastula.   Cleavage soon produces a ball of cells in eggs with minimum yolk.   This is called a *morula* and is best seen

Fig. 305. — A, Blastula; B, Gastrula.

in this type of egg.   As segmentation advances a cavity appears inside.   This stage is called the *blastula* (Fig. 305 A).   It is like a hollow ball whose wall is composed of one layer of cells.   The cavity within is the *segmentation cavity*.

Gastrula (Fig. 305 B).   Gastrulation is the process by which endoderm is formed.   For example, the cells at one place in the blastula grow in by a process of *invagination* which is an infold-
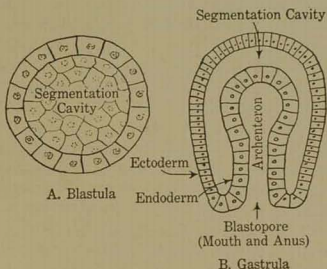
ing by growth so that what was an outer surface becomes an inner surface. It continues until the inturned cells form a blind sac, which in some cases is in contact with the outer cells. A two-layer double sac-like stage is produced. The inner layer of cells forms the *endoderm*. They may be a little larger than those of the outer *ectoderm* layer. The space, if any, between ectoderm and endoderm is still the segmentation cavity. The mouth is called the *blastopore*. The cavity within the endoderm is the *archenteron* or primitive gut. There are now two primary *germ layers*, ectoderm and endoderm. The ectoderm may be regarded as related to functions of *adjustment;* the endoderm, to functions of *metabolism.* A review of the anatomy of Coelenterates shows that they are but specialized gastrulae.

Origin of Mesoderm. The origin of the mesoderm is diverse. There is none in Porifera and Coelenterates. It first appears in Platyhelminthes and occurs in all higher phyla. Mesoderm may arise from primary mesoblast cells (mesoderm formers), appearing in the segmentation cavity and originating from endoderm as in the earthworm (Fig. 170). Mesoderm in different animals originates from either ectoderm or endoderm or both, but usually from endoderm. In any one type it always forms in the same way. Mesoderm develops in three ways.

First: The Enterocoelic type. This happens in many invertebrates and among lower Chordata. Mesodermal pouches are formed by evaginations from the lateral walls of the embryonic gut, beginning at the anterior end. The pouches enlarge, obliterating the segmentation cavity and are soon detached from the gut wall, thus forming sacs. With further enlargement, the enterocoelic pouches come in contact with the external ectoderm externally; with the wall of the gut internally; and the faces of successive pouches are in contact with each other. In the earthworm these transverse walls become the septa of the adult worm and the pouch cavities form the coelome. In many forms, however, these walls disintegrate, thus forming two continuous cavities on either side of the gut (endoderm) and inside the body wall (ectoderm). That portion adjacent to the ectoderm is called *somatic mesoderm* (Fig. 306) and that adjacent to the endoderm (gut) is called *splanchnic mesoderm,* the cavity between the two being known as the *coelome* or *body cavity.* While the above changes are going on, the enterocoels on either side of the gut have enlarged

until they meet ventrally underneath the gut, where their adjacent walls form a vertical sheet of tissue connecting the lower midline of the gut to the ventral midline of the body wall. This sheet of supporting tissue is known as a mesentery. It remains in many invertebrates, but in the vertebrate soon disappears. Thus in the latter, one continuous coelome is formed. In a somewhat similar way a dorsal mesentery is formed which remains throughout life in the vertebrate, connecting
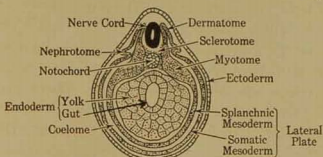

FIG. 306. — Diagram of cross-section of young amphibian embryo.

the intestinal tract to the dorsal midline of the body cavity and acting as a suspensory medium.

Second: Mesoderm also originates by the splitting off of a layer of cells from the endoderm along the dorsal midline of the embryo. This is known as *delamination.* The delaminated layer splits later into somatic and splanchnic mesodermal sheets and coelome as before.

Third: In most of the higher vertebrates mesoderm originates from the undifferentiated tissue where endoderm and ectoderm fuse along the dorsal midline of the embryo, these eventually forming the somatic and splanchnic layers as before, with the coelome between.

The Fate of the Germ Layers. Each of the germ layers, ectoderm, mesoderm and endoderm, develop quite uniformly into particular adult structures.

(*a*) Ectoderm forms the epidermis of the skin, skin glands, hair, feathers, nails, hoofs, lining membrane of the mouth and anus, parts of the eye and ear and the nervous system.

(*b*) Mesoderm develops into the soft connective tissues, cartilage, bone, skeletal muscles, heart, blood vessels, blood, most of the urinogenital system and the connective tissue and involuntary muscle of the alimentary tract.

(*c*) Endoderm forms the lining (mucous) membrane of the gastro-intestinal tract, the multitudes of small glands in this tract and the larger glands such as the pancreas and liver, the lining of the respiratory system, the glandular portions of the thyroid and thymus glands.

Notochord. In Amphioxus (Fig. 227) a linear group of cells along the dorsal midline of the embryonic gut (endoderm) develops into the notochord, which later becomes separated from the gut and extends the length of the body above the gut. In Vertebrates the notochord is formed in much the same way. The possession or formation of a notochord is one of the unifying features of the Chordates. It is a firm rod of soft cells, which in most Vertebrates is but a temporary structure existing during development (Fig. 307). It soon disappears, being replaced first by a cartilage and later by bone (backbone), in animals that have a bony skeleton.

Dorsal Nerve Cord. A second common characteristic of Chordata is the embryonic nerve cord, which develops into the central and peripheral nervous system. It is located above the
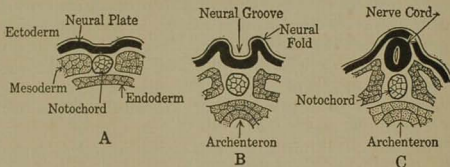

FIG. 307. — Diagrams illustrating formation of central nervous system.

notochord and above the gut, quite the opposite of its position in annelids and arthropods.

In the frog embryo, about the time the gastrula is formed, the ectoderm forms two or more layers of cells. Along the dorsal surface the ectoderm thickens, forming the *neural plate* (Fig. 307 *A*), which extends forward into a wide, rounded front portion. Then the margins of the plate thicken to form lateral neural folds between which is a depression, the *neural groove* (Fig. 307 *B*). The neural folds grow higher, the groove deeper and the folds grow toward each other and join, forming the neural tube (Fig. 307 *C*), which is beneath the outer ectoderm. The anterior enlarged portion of the neural tube develops into the brain, while the more slender posterior portion becomes the spinal cord. The peripheral nerves develop from cells in the neural tube.

Developing Mesoderm (Fig. 306). The mesoderm described above gradually develops into three well-defined masses of cells.

First: The first of these is called the Lateral Plate and consists of the greater part of the somatic and splanchnic mesoderm with the coelome between.

Second: A mass of mesoderm cells on either side of the nerve cord and notochord in the dorsal-median portion of the embryo forms a long strip of tissue called the *segmental plate*. This increases in thickness. By a series of transverse divisions, beginning in front, the segmental plate is cut (by growth) into a succession of blocks of tissue called *somites*. In cleared preparations of embryos these can easily be seen. Their number is an index of the age of an embryo. They are homologous with the somites of the earthworm and the myotomes of Amphioxus and appear in embryos no matter whether mesoderm is formed by enterocoelic pouches, delamination or proliferation. They are considered as one of the characteristics joining Chordata to organic relationship with Annelids.

Each somite develops three special regions: (*a*) The *dermatome*. This is thin and lies laterally just beneath the adjacent ectoderm. It develops chiefly into the dermis of the skin. (*b*) *Myotome*. This portion is thicker and medial to the dermatome. It is the chief originator of the voluntary muscles. (*c*) *Sclerotome*. This is a mass of loose cells between the myotome and the notochord. From this mass of cells the axial skeleton is formed.

Third: There remains a small mass of cells in the upper lateral part of the body cavity between the lateral plate and the somites. This mesodermal tissue is called the *nephrotome*. From it will develop the greater part of the excretory system.

The somatic mesoderm of the lateral plate forms the outer wall of the pericardium, pleurae, and peritoneum; while the splanchnic layer forms the heart, inner wall of the pericardium, pleurae and the mesenteries, and connective and involuntary muscle tissues of the gastro-intestinal tract.

Further Developmental Stages. As gastrulation, in the *frog*, continues, the body lengthens, a permanent antero-posterior and dorso-ventral differentiation is established and the embryo is bilaterally symmetrical (Fig. 308). Externally the head region and body regions are outlined. On the antero-ventral surface of the head appears a pair of slight outgrowths marking the position of the optic cups forming from the brain within; to the side and

below these, a pair of nasal pits later to form part of the nasal passages; on the lateral surfaces of the head are shown ridges
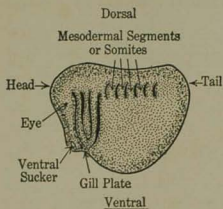
marking the developing gill arches between which are grooves where the future gill slits will appear. A pit develops from invagination at the posterior end of the embryo, below the blastopore. The latter closes, while the invagination continues until the passageway is connected with the hinder part of the embryonic gut. This newly formed passageway is the *procto-daeum* and its external opening is the *anus*. Similarly a pit, originating by invagination of ectoderm, forms on the front ventral surface

Fig. 308. — Young frog embryo. From Curtis and Guthrie, *Textbook of General Zoology*, copyright 1927, John Wiley & Sons. Reprinted by permission.

of the head. This continues until it connects with the blind front end of the embryonic gut, forming the *stomodaeum* and its *anterior opening* is the *mouth*.

External gills which are small tufted processes grow out from the gill plates before hatching and are functional for a time after hatching. Blood from the newly formed heart is pumped out to capillaries in these gills, and after aeration the blood passes back to a dorsal aorta to be circulated throughout the body. The external gills are soon replaced by so-called internal gills bordering on gill slits which have formed in the wall of the pharynx between the gill arches. The embryonic circulation is shifted to these new gills. Both gills and the circulatory system involving them are similar in many ways to those of fishes.

The different regions of the intestinal tract gradually differentiate (Fig. 309). Evagination of a solid mass of cells in the floor of the back part of the pharynx is the first indication of the future trachea and lungs. Similarly the liver begins as a proliferating mass of cells from the floor of the fore-gut. The first part originating from the gut becomes the bile duct. Nearby develops the pancreas. From the floor of the posterior region of the intestine develops the cloacal bladder. Proliferations of cells from the first and second pair of gill clefts form a mass of cells destined to become the thymus gland. On the floor of the pharynx back of the glottis,

in the midline, a rod-like mass of cells is formed which later develops into the thyroid.

The anterior enlarging end of the neural tube has by constriction formed the three embryonic regions of the brain (Fig. 309), namely, the *fore, mid* and *hind* brain. From the fore brain develops the prosencephalon or cerebral hemispheres, and the diencephalon, to which the pituitary gland is connected. The mid brain develops into the mesencephalon which bears the optic lobes, while the hind brain develops into the metencephalon or cerebellum and the myelencephalon or medulla.
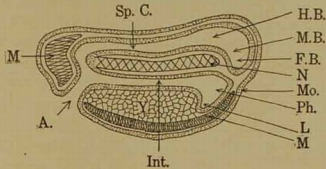

FIG. 309. — Longitudinal vertical section of early frog embryo. *Sp. C.*, spinal cord; *H.B.*, hind brain; *M.B.*, mid brain; *F.B.*, fore brain; *N*, notochord; *Mo.*, mouth; *Ph.*, pharynx; *L.* liver; *M* mesoderm; *Int.*, intestine; *Y*, yolk; *A*, anus.

From each of the sides of the fore brain an evagination forms a saccular outgrowth, the optic vesicle (Fig. 310). As development proceeds these are connected to the brain by optic stalks. When the optic vesicles reach the external ectoderm, a thickening appears there. The outer wall of the optic vesicle just opposite this new thickening now invaginates, forming a double-walled optic cup. The thickening just spoken of later forms the lens of the eye. The inner inturned wall of the optic cup develops into the retina. The outer wall of the cup forms the pigmented layer behind the retina of the adult eye. The rods and cones, sensory cells of the retina, are connected with special nerve cells which, forming here, grow toward the brain along the optic stalk and so form the optic nerve.
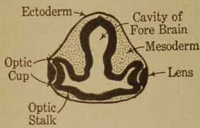

FIG. 310. — Section through head of amphibian embryo, showing development of eye.

The choroid coat of the eyeball outside the retina and the sclerotic coat outside the choroid are both formed from wandering mesoderm cells.

Special attention has been called to the external and internal gills which the early frog embryo and tadpole develop. It is of

interest to know that elasmobranch embryos develop external gills before their internal gills appear. The formation of gills involves also the special development of arteries and veins to connect the gills with the heart and central circulatory system. When metamorphosis takes place in the tadpole, and gills give way to lungs, this profound change necessitates a corresponding change in the circulatory system. The embryos of reptiles, birds and mammals never develop gills but they *do* develop gill arches, gill slits, and also the embryonic circulation for a time appears to be adjusted to a gill type of circulation although there are no gills. But the embryonic gill slits are evanescent structures as are also

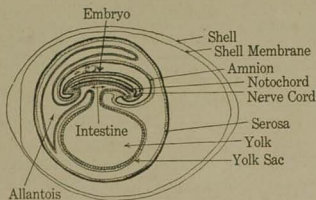the early circulatory structures related to them.

FIG. 311. — Chick embryo in shell showing relations of amnion, allantois and yolk sac to embryo. Modified from Arey (from Prentiss), *Developmental Anatomy*, W. B. Saunders Co., 1926.

Allantois and Amnion. In Reptiles and Birds, the embryo develops in a disc of cells on the yolk inside the white of the egg and its shell. An early indication of the embryo is a thickening in the middle of this disc. The development of organs occurs as before, but the periphery of the disc grows down around the yolk. The superficial layer of the disc is ectoderm lined with mesoderm, or somatopleure; while next to the yolk is splanchnopleure or splanchnic mesoderm and endoderm. Between the two is coelome. A fold of somatopleure (ectoderm and mesoderm) grows up in front of the head. Similar folds appear on each side of the embryo and behind. These folds grow up around the embryo and meet above it. They are double and, after they meet, the inner layers fuse with the inner layers and the outer layers fuse with the outer layers. The fusion of the inner layers forms a sac, the *amnion*, which incloses the embryo (Fig. 311). Above this is the *serosa*, formed by the fusion of the outer layers of somatopleure. The amnion sac is filled with a fluid bathing the embryo. Externally, the amnion and serosa are in contact unless prevented by presence of some other structure. The amniotic fluid protects

the embryo from physical shocks when the egg is moved. The splanchnopleure grows around until it encloses the yolk, thus forming a yolk sac. This is connected with the embryonic gut.

As the amnion is growing, a sac called the *allantois* grows out from the floor of the hind gut. This is therefore composed of splanchnopleure. The allantois grows out between the amnion and serosa. In the allantoic walls develop veins and arteries which are in connection with the blood system of the embryo. The allantois is close to the porous shell and is a respiratory organ for the embryo. Oxygen enters through pores in the egg shell, and into the capillaries of the allantois and so to the embryo. In reverse fashion the CO_2 passes out. Wastes of later embryonic development collect in the allantois. The yolk in the yolk-sac is gradually absorbed. When the animal is ready to hatch, it bursts through the amnion, serosa and shell, and is parted from these now useless structures. The allantois is homologous with the cloacal bladder of Amphibia.
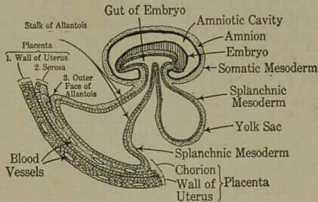

Fig. 312. — Mid-sagittal section of foetal membranes and allantoic placenta of a pig embryo. Modified from Arey (from Prentiss), *Developmental Anatomy*, W. B. Saunders Co., 1926.

Placenta (Fig. 312). The placenta, as has been described, is a structure which vitally connects mammalian mother and offspring. It is formed by a union between a portion of the uterine wall and part of the chorion, which is a union between the serosa and the distal part of the allantois. The allantoic structures of *Sauropsida*[1] are retained and used in a new way, due to the absence of yolk and due to a superior method of rearing, which is wholly intra-uterine.

In the mammal embryo, amnion and allantois are formed. The true amnion forms a sac filled with liquid in which the embryo lies protected. The outer face of the vascular allantois is in close connection with the inner face of part of the serosa and these two

[1] Huxley combined reptiles and birds into the group, Sauropsida because they were so similar, anatomically.

form the chorion, which is in contact with the wall of the uterus. Both uterine wall and chorion grow in thickness where they are in contact. The peripheral ends of uterine and foetal blood vessels become large sinuses where the uterine wall and chorion meet and develop the placenta. These foetal and maternal sinuses dovetail and interlock. The maternal blood is very near to the foetal blood. (See Fig. 270.) The umbilical cord connects the foetus with the placenta. It is covered with ectoderm and consists chiefly of a soft (mucous) tissue which supports the yolk stalk, the stalk of the allantois, two allantoic arteries and the large allantoic vein. There are different types of placentae. In the Primates (man) it is *discoidal,* or saucer-shaped, and is in intimate connection with uterine tissues. From the center of the inner face originates the umbilical cord.

Law of Recapitulation. In review it is important to note that: (a) Most sexually reproduced animals begin life as a *single cell,* the fertilized egg. This might be called the protozoan stage of development. (b) Early cleavage stages form a *morula,* a spherical group of cells. Associations like this are found in Protozoa, for example, Pandorina. (c) Later cleavage produces a *blastula,* a hollow ball of cells. Volvox is like this. (d) Later, the embryo forms a *gastrula.* Hydra and Coelenterates have this body plan. (e) Reptile, Bird and Mammal embryos have gill slits and gill arches and never use them. They are adult structures in fishes and in some Amphibia.

It appears from this review that the higher animal in its development recapitulates its own ancestral history, presenting, as it were, a sort of synopsis of a few of the morphological stages passed through. Von Baer, in 1828–34, making a general and comparative study of the embryology of animals, concluded that early in development widely separated animals, such as Reptiles, Birds and Mammals, had so many characters in common that it was difficult to distinguish between them; and that development proceeded from a general to a special type.

Fritz Müller, in 1863, expressed the opinion that the embryological history of an animal indicated ancestral stages through which it passed. Haeckel in 1874, accepted and overemphasized this theory. It is known as the Recapitulation Theory or Biogenetic Law, *i.e.,* ontogeny recapitulates phylogeny; an animal in its development goes through stages which indicate its ancestors.

Starfish, earthworm, snail, amphioxus, frog, reptile, bird and mammal have a gastrula stage — which indicates that their ancestor was a coelenterate-like animal. The fact that they all start from a single cell means that the most primitive ancestor of all animals was a protozoan-like form. The formation of gill slits and other features in reptile, bird and mammal embryos show their fish-like ancestry. Though these phenomena are significant, yet some enthusiastic adherents of this theory went far afield to interpret all embryological structures in terms of the phylogenetic law. But embryological development is not *merely* the recapitulation of ancestral history. Three weeks elapse between the beginning of cleavage and the hatching of a chick. How could all the stages in the evolutionary development of birds be exhibited during such a brief embryological period? After a long period of research, inspired by the phylogenetic theory, embryologists gradually came to the conclusion that the application of the law was limited, although this does not mean that parallelism in development is without evolutionary significance.

Preformation and Epigenesis. It seems axiomatic to anyone who studies the embryology of an animal from the fertilized egg that a large and complex organism develops from an apparently simple microscopic mass of undifferentiated protoplasm. Charles Bonnet, who first discovered parthenogenesis in Aphids, philosophized deeply concerning development. He satisfied himself, at least, that, after all, there was no development, but that the egg contained in its small compass all the parts of the adult. Nothing new appeared, only the gradual unfolding of what preexisted took place. Thus there arose the embryological doctrine of *preformation*. Bonnet carried the idea to absurd limits. If the animal is preformed, an animal of the next generation is present in it in still smaller compass and so on ad infinitum. All thinking along embryological lines was dominated by this idea during the seventeenth and eighteenth centuries. It was even computed that Eve, the mother of all men, possessed 200,000 millions of homunculi (little men) in her ovary. Indeed, the preformation school divided into the *Ovists* and *Animalculists*. According to the former, the egg contained miniatures of future descendants. But spermatozoa had been discovered and so others (Animalculists) believed that the sperm alone functioned and that the eggs were only soil in which the organism resident in the sperm could develop.

Speculation followed speculation. In 1759, Wolff checked all this by conclusions based on painstaking observations on the development of the chicken, and published a paper called " *Theoria Generationis.*" He showed that the early embryo contained no future parts, but that the organs appeared gradually one after the other. From early simple substance, differentiation to later complexity took place. In other words, there was no mere unfolding of parts already formed. This is known as the *Doctrine of Epigenesis.* The zygote is a generalized cell capable of developing by a long series of mitoses, the differentiated tissues and special organs of the adult.

Prelocalization. Experiments carried on during the latter part of the nineteenth century demonstrated that not *preformation* but *prelocalization* is true of some eggs. For example, in the egg of Cynthia, a Tunicate, the cytoplasm of the egg shows five different zones or bands of protoplasm: first, clear; second, light gray; third, dark gray; fourth, light yellow; fifth, dark yellow. As development proceeds these are parceled out to definite groups of cells and organs. The clear protoplasm becomes *ectoderm;* the dark gray becomes *endoderm;* the yellow becomes *mesoderm.* If the egg is punctured and the clear substance removed, the embryo possesses no ectoderm and can produce no ectodermal structures. Of course, such an embryo does not mature. These experiments demonstrate a kind of prelocalization. Other eggs are not differentiated so early as the one-cell stage. This is known to be true of the eggs of the sea-urchin and Amphioxus. If such an egg is punctured and some of the cytoplasm is removed, a perfect embryo results. If in the two-cell stage one is destroyed or the two separated, perfect embryos result. Any cell of the 4- or 8-cell stage has the power of forming a perfect but smaller embryo. Sooner or later, but comparatively early, however, differentiation appears and after this stage, such fragments die. Indeed these experiments show the truth of both preformation and epigenesis, for they demonstrate the gradual development of the complex from the simple as well as showing prelocalization.

Identical Twins. The experiments also throw light on the origin of such twins. It is thought that the fertilized egg begins to develop normally but at an early stage separates into two growing centers, each of which develops into a perfect mature organism and both are remarkably alike. When one stops to consider the similari-

ties in stature, figure, features, hair color, eye color and even mental characteristics of two identical human twins, each derived from half of a mere speck of protoplasm one is forced to conclude the generalized conditions of the germinal cell and the equal distribution in it of all its elements. Although there are definite indications of prelocalization of egg cytoplasm, yet a still more significant organization is present in the chromosomes and is discussed in the study of Genetics.

Abnormal Development. The course of development does not always run smoothly. Departure from normal environmental conditions modifies normal development. Possibly unusual chemical conditions change it. Abnormalities often appear. Organs are misplaced or incomplete, or lacking, or out of proportion, or doubled. One or both legs may be lacking or one or both arms or there may be more than four limbs.

Experimental Embryology. Experiments on eggs and embryos of lower forms throw light on these matters. If the developing limb bud of a frog is destroyed, no limb will develop because all the "limb-forming substance" is destroyed. Suppose the two-cell stage be partly separated. Then a two-headed and one-bodied embryo may develop, or one-headed and two-bodied or two-headed, one-bodied and two-tailed, depending upon how and where the cells are separated. All sorts of combinations have been produced. If a light weight such as a cover glass is placed on the developing egg of the starfish, for example, a flat plate of cells soon appears. If the weight is continued further, a very abnormal embryo is formed. In cold-blooded animals, it appears that if the temperature is lowered where eggs are developing, the developmental rate is slower and the same is much more rapid than usual if the temperature is raised. If eggs develop under conditions of extreme temperatures, abnormalities occur and of course death, if the temperature limits are further changed. By adding certain salts such as those of magnesium to sea-water in which eggs of marine fishes are developing, a variety of monstrosities result, as, for example, an animal with one eye, a cyclops, formed by the fusion of both optic vesicles.

If the two-cell stage in development is divided into the two component cells, each of the latter, in the case of certain animals, will develop into a perfect embryo. If the same experiment is performed on the eggs of other animals, imperfect half embryos

develop. If a fertilized egg is divided into two pieces, so that one piece contains the nucleus and the other has no nucleus, both pieces may be fertilized and each will form an embryo. The first piece possesses the egg chromosomes ($\frac{1}{2}$) and to these are added those of the sperm ($\frac{1}{2}$), and in spite of the fact that only part of the usual cytoplasm is present, an embryo forms. But the other piece of the egg has *no* chromosomes and so in fertilization it has only one half the usual number, yet an embryo sometimes forms. It is found, however, that the later cells, *i.e.*, 2-, 4-, 8-, etc., each have the usual number. This is brought about in the following manner. A mitotic spindle forms in the fertilized enucleated piece, and the half chromosomes divide, forming the usual somatic number, but the cell does not divide. When it does divide, each of the first two cells and later ones receive the full complement of chromosomes.

Prenatal Influences. We shall later discuss the fundamental importance of heredity in determining what kind of an individual shall develop from a fertilized egg. We shall have occasion to point out evidences that indicate that the egg and sperm contain multi-molecular and ultra-microscopic bodies called genes which determine at the time of fertilization the characteristics that will appear when the zygote has developed. We are not concerned just now with arguments for or against Weismann's contention that environmental changes do not affect the germ plasm. The present day expression of Weismann's position would be as follows: Environmental conditions changing the body do not change the genes. This question aside, it is nevertheless true that the ever-varying external and internal environment does affect the developing zygote. The zygote may start with perfect genes, but conditions may appear during the embryological period that may distort the normal course of development of the genes.

Many people believe that abnormalities are directly due to prenatal mental influences; that shocking incidents so impress the mother as to affect the normal development of her child and mark it in some way. A common story is this: A pregnant mother was frightened and shocked at the sight of a mad dog biting a child on the arm. As a result her baby, when born, showed a red scar in a corresponding place. There is no scientific connection between the phenomena. Many babies have been born with scars on their arms, although their mothers never saw a

mad dog. Mothers surrounded by the most favorable conditions during pregnancy have been known to give birth to abnormal offspring. Of course the abnormality must have had a cause, but the possibility of any specific effect of mental conditions of the above sort is highly improbable.

Telegony. Somewhat related to the popular notion of prenatal influence is belief in Telegony. Some animal breeders believe that breeding a pedigreed female to a low-grade male so affects the female that her *later* offspring, even though fathered by a *pedigreed* male, show taints of the former low-grade mating. There is no well-founded evidence for this belief. Understanding of the processes of reproduction involved, negatives the possibility of such an effect. The only vehicle by which the low-bred male could have affected the female was his spermatic fluid containing sperm cells. Neither remain potent for very long. They could not affect later matings. If a pair of pedigreed stock produce inferior offspring, it is far more likely that the inferiorities which appear are the outcroppings of inferiorities possessed by the ancestors of one or the other of the pedigreed parents. An explanation of reversions which are common occurrences is presented in the discussion of genetics.

Conclusion. Lured by the hope of finding ever more convincing evidences in proof of the law of Recapitulation, embryologists of the last century worked out in accurate detail the embryology of a host of forms of animals. As limitations of the application of this law increased, scientists lost interest in this sort of research. However, the successive events in the development of animals representing every phylum had been satisfactorily recorded, but the accomplishment of this monumental task did not satisfy the new recruits. The description of what takes place, step by step, does not explain the process of development. What causes the orderly succession of increasingly complicated differentiation? What forces in the blastula cause the formation of the gastrula? Why should a minute speck of protoplasm which we call a human zygote develop into a human being? What is the nature of the marvelous organization of the egg that in the normal course of events produces such a result?

Turning from the earlier morphologically descriptive embryology, investigators attempted to discover the nature of the processes of development by resorting to experiments such as have

been indicated above. When discordant results were obtained with different eggs, certain experimental embryologists decided that such work was futile. One of the most brilliant of these investigators, Driesch, went further than this. He concluded that the activities of the organism and of its cells and of cells at every stage in life were presided over, or governed, or directed by a mystical force or principle which he called "Entelechy," whose nature could not be ascertained by the tools or methods of physical science. This philosophy is called Vitalism. It stifles any progress in increasing our knowledge of the processes of life. On the other hand, many investigators, by using the tools and methods of physical science, have added a great deal to our understanding of the embryological problem.

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