A TEXTBOOK OF BIOLOGY

W. M. SMALLWOOD

A TEXT-BOOK

OF

BIOLOGY

FOR STUDENTS IN MEDICAL, TECHNICAL AND GENERAL COURSES

BY

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TO

THE MEMORY OF MY MOTHER

ELOISE MARTIN SMALLWOOD

EVER MY COMRADE IN THE

WORLD OF BOOKS

PREFACE

THE earliest biologists devoted themselves to a study of the whole organism, and Linnaeus (1707 to 1776) made his descriptions of the external features so accurate that many of them have been retained to the present day. During this same period the working organisms as a whole appealed to Haller (1708 to 1777), who became famous for his discoveries. Thus early were clearly defined the two general lines of study, namely, morphology and physiology, which have now become distinct sciences. As the knowledge of the parts of organisms became more exact they were found to be composed of organs, and two names stand out prominently among those advocating their study: Cuvier (1789 to 1832) gave to the morphological study of organs a greater importance than his predecessors, and Müller (1801 to 1858) a little later threw into prominence the function of organs. Next the organs were found to be made up of tissues, and Bichat (1771 to 1801) gave particular attention to their composition and work. All of the investigations up to this time had failed in part because the ultimate structure of the organism was unknown. With the discoveries of Schleiden and Schwann (1836 to 1840), that all living things can be analyzed into cells, a morphological basis for biological study was established. The name of Virchow (1821 to 1903) is linked with the physiological study of cells. Dujardin (1801 to 1860) gave a great deal of attention to protoplasm, and Bernard (1813 to 1878) emphasized the importance of protoplasm in analyzing physiological activities. We thus come through a series of historic steps to the modern point of view which seeks to interpret biological problems in terms of protoplasm.

The historical development of biology as thus outlined furnishes a natural and logical plan of study for the beginning student. The earlier chapters (I–IX) of this work, accordingly, take him through a consideration of the organism as a whole, the structure and function of organs, the structure and properties of tissues, and the parts of the cell and their work. The chapter devoted to the biology of cells furnishes the basis for the modern point of view and acts as a background for the remainder of the book. Chapters XII and XIII are included at the request of medical educators who ask that medical students shall have some conception of the animal kingdom as a whole. These chapters are not intended for students who take advanced courses in botany and zoölogy.

It is expected that work in the laboratory will always precede the discussion of the text, and each chapter is written on the assumption that the student is already in possession of certain facts which he has gained from his own accurate observation.

In attempting to cover so wide a range of topics, the writer has relied to a large extent upon numerous works of research, and to the authors of these he is greatly indebted, though he has mentioned by name only those from whose work he has made quotations. The facts from these researches have been selected to illustrate biological principles, and it is the development of such principles which is the chief aim of this volume. At the close of certain chapters special references are given where there is a recent point of view, as in Chapter I, or where the topic is relatively new as in Chapter XVIII. The writer wishes further to acknowledge especially his indebtedness to Holmes' *Biology of the Frog*, Jordan and Kellogg's *Evolution and Animal Life*, Marshall's *Microbiology*, Thompson's *Heredity*, Darwin's *Origin of Species*, and to thank Professor Yerkes for permission to make extensive excerpts from his works. From his own book, *Animal Biology*, the writer has drawn freely.

Nearly all of the illustrations have been intentionally selected from material which will not be a part of the regular laboratory work. The principles are thus illustrated and the student has no temptations to copy text drawings and substitute them for his laboratory observations. The illustrations also add many new facts that supplement the laboratory work and text, and should be studied with this point in mind. Professors Castle, Pearl, Reichert, and Smith have kindly furnished me with the illustrations with which they are credited. Most of the others have also been taken from original researches and the source acknowledged.

Chapter XI was read by Professor H. D. Ward, Department of Bacteriology, Syracuse University, and by Professor Wm. Crocker, Department of Plant Physiology, Chicago University. Chapter XIII was read by Professor W. H. Bray, Department of Botany, Syracuse University, and the facts in regard to the number of species were

furnished by Professor Crocker. Chapter XV was read by Dr. F. Meader, City Bacteriologist of Syracuse. The whole text has received a careful revision by Dr. Frank Knowlton, Professor of Physiology in Syracuse Medical College. To these several friends the writer expresses his gratitude and records his obligations. In the preparation of the manuscript and the reading of the proof the writer has had the constant help of his wife.

W. M. S.

Syracuse, N. Y., 1913.

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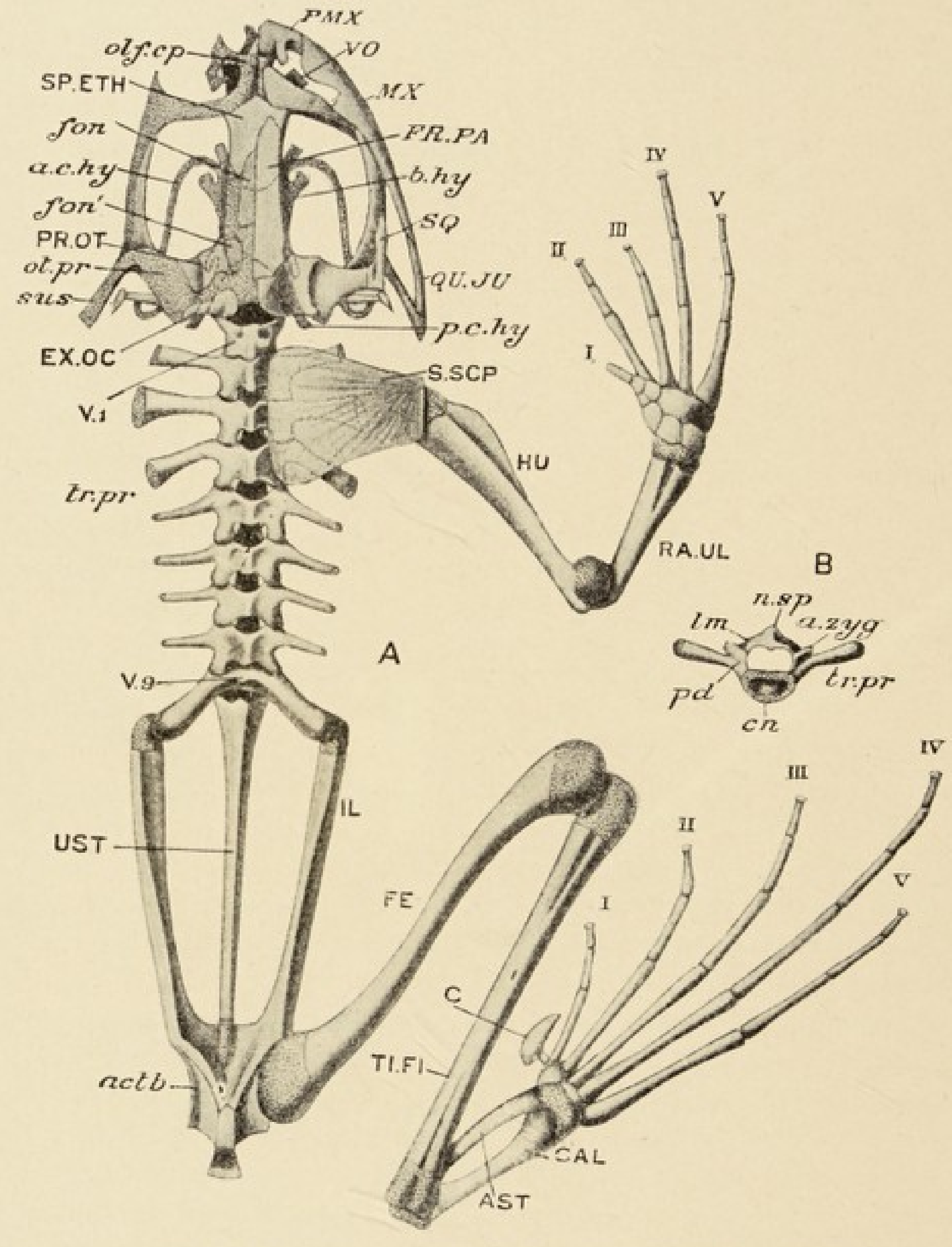
CHAPTER I

ORGANISM

Laboratory Study.—Living Frog: Observe use of the various parts in sitting, jumping, swimming, and breathing. Character of skin and distribution of color. Examine the various openings of the body and the position of the several sense organs. Work out the parts of the limbs and division of body into head and trunk. Make accurate sketches.

Movement.—The steam engine, the printing press, or gliding aëroplane never fail to excite our admiration. The complicated machinery operates on almost frictionless bearings in accomplishing marvellous results, but none of these wonderful products of the inventive skill of many minds equals the frog when considered simply as a machine. Jumping and swimming involve a series of movements that are much more complicated than simply straightening out the limbs. Each limb takes a definite direction, one that is selected, and this alone places the movement of a limb as superior to the most perfect machine. In order that there may be selection in the direction of the movement of a limb, there must exist muscles capable of causing the limb to go in a given direction; but muscles need something to which they can be attached in order to make these selected movements. Such a framework is furnished by the bones. Bones and muscles alone are not capable of producing a given result. There must be a directing agent, something responsible for the movement and the selection. This is the work of the central nervous system and of the nerves that end in each muscle. The frog thus analyzed is easily seen to be more complicated than any machine. One of the reasons why the term living is given to the frog is because it can make these selective movements of the limbs. For the name frog may be substituted the name of any other thing that has biologically, not humanly speaking, this same

Fig. 1



Rana temporarai. *A*, the skeleton from the dorsal aspect; the left half of the shoulder girdle and the left fore and hind limbs are removed, as also are the membrane bones on the left side of the skull. Cartilage parts dotted *a. c. hy.*, anterior cornu of hyoid; *actb.*, acetabulum; *ast.*, astragalus; *b.hy.*, basihyal; *c.*, calcar; *cal.*, calcaneum; *ex.oc.*, exoccipital; *fe.*, femur; *fon. fon'.*, fontanelles; *fr.pa.*, frontoparietal; *hu.*, humerus; *il.*, ilium; *mx.*, maxilla; *olf. cp.*, olfactory capsule; *ot. pr.*, otic process; *p. c. hy.*, posterior cornu of hyoid; *pmx.*, premaxilla; *pr.ot.*, proötic; *ra.ul.*, radioulna; *sp.eth.*, sphenoethmoid; *sq.*, squamosal; *s.scp.*, suprascapula; *sus.*, suspensorium; *ti.fi.*, tibiofibula; *tr. pr.*, transverse process; *ust.*, urostyle; *v.* 1, cervical vertebra; *v.* 9, sacral vertebra; *vo.*, vomer; *I-V*, digits; *B*, the fourth vertebra, anterior face; *a.zyg.*, anterior zygapophysis; *cn.*, centrum; *lm.*, lamina; *n. sp.*, neural spine; *pd.*, pedicle, *tr. pr.*, transverse process. (After Howes, slightly altered, from Parker and Haswell.)

property of exercising choice in its movements and the term living can be applied to it.

There is movement in a variety of things in Nature. A familiar example is that of the wind. While the usual paths of the wind are known and charted, and the cause of the wind is largely in the difference in temperature and barometric pressure, yet there is nothing that is comparable to the selected direction of movement in a living animal. Gunpowder and the various explosives have each a characteristic movement, but they all remain in a static condition unless acted upon by some outside stimulus as the lighted fuse, and then their movement is of one kind. Movement considered from a physical or chemical standpoint is of the same nature whether in inanimate or animate Nature; but there is always in animate movements the additional regulative factor which permits movement to be regarded as one of the fundamental properties of living matter. There are seasons or periods in the life of many animals when movements cease and the animal becomes quiescent. This is illustrated in the habit of hibernation of the frog and many other animals.

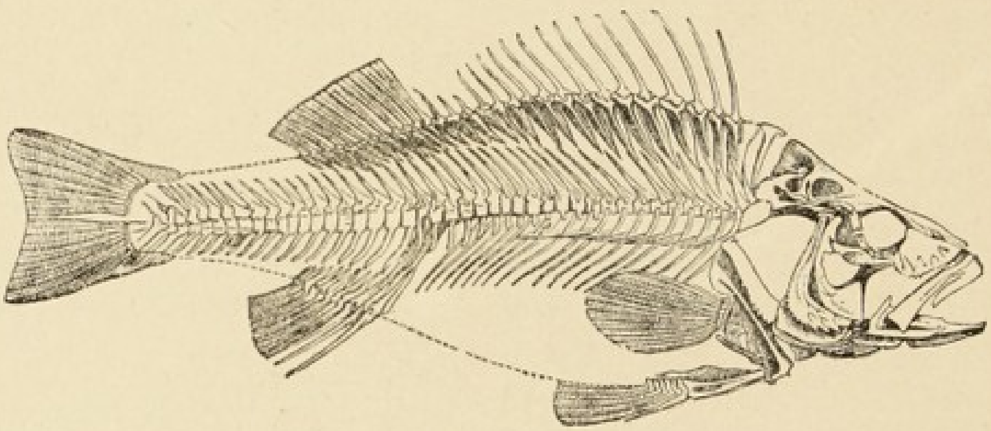
The four legs of the frog move in such a manner as to produce a given result, the two eyes reveal the same picture, the complicated changes in breathing result in drawing air into the lungs and allowing it to escape and many other equally difficult changes are taking place continually. Any thing which can produce these peculiar changes is alive and is called an organism.

Organism Defined.—The term organism is given to any particle of living substance capable of independently sustaining itself. "An organ is individual, is a unitary mass of living substance which under definite vital conditions is capable of self-preservation." This definition is so formulated as to include every condition under which living things have come to live, the minute bacteria or the large elephant, the simple worm or the group of individuals in the ant community.

These definitions include all forms of living things but because many of them are so simple the following "An organism is composed of organs" does not apply although it describes and defines correctly the frog as it does all large animals, and is the most used and familiar definition. Whenever this latter definition can be used, the animal is complex, consisting of many highly specialized parts as arms, legs, eyes, ears, taste and touch organs, etc. Each of these has a given work to do and is called an organ. Only a few of the organs in the frog have been observed as yet in this course but others will be worked out later. *An organ* is a structure which does a given work for the organism and is itself composed of many distinct parts.

Amphibia.—A long time ago when men first became interested in animals they arranged them into certain groups, because all of the members of the group possessed certain structures in common. The head and trunk of the frog at once suggest that is belongs to a higher group of animals than the earthworm or crayfish. The internal skeleton shows that there are a number of separate bones joined together in the back to form what is termed the vertebral column. The presence of these serially arranged bones at once places the frog in the very general class of vertebrata and an examination of Figs. 1 to 6 shows how closely the frog is related to these other animals. There are a number of animals that have frog-like

FIG. 2



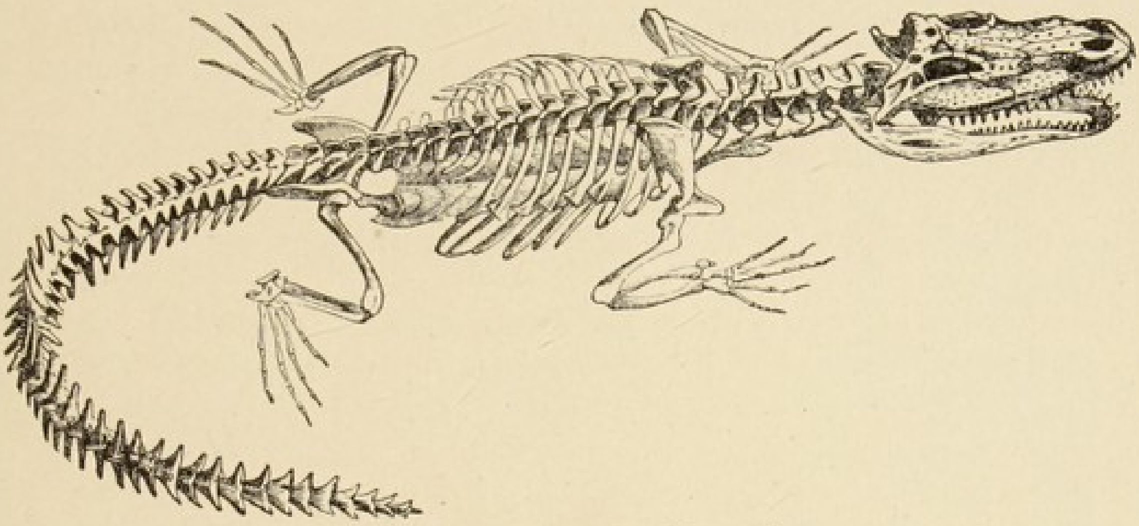
Skeleton of a fish. (Kny-Scheerer Co.)

skeletons, a soft, moist, naked skin, pentadactyl appendages, and frog-like habits, which are arranged under the general subclass of amphibia which is one of the five great classes of vertebrates. Each of these large groups of the vertebrates is subdivided into many genera, families, etc., so that one finally comes to the frog family, Ranidæ, and the more critical study considers the exact species (see Chap. XII).

Habits.—While the Amphibia are all aquatic for a part of the time and but few (toads) of them remain away from the water for any length of time, it is not practical to describe the habits of the group but rather of some definite animal. The frogs collected for laboratory study in New York State are the leopard frog (*Rana pipiens*), and the large bull frog (*Rana catesbiana*).

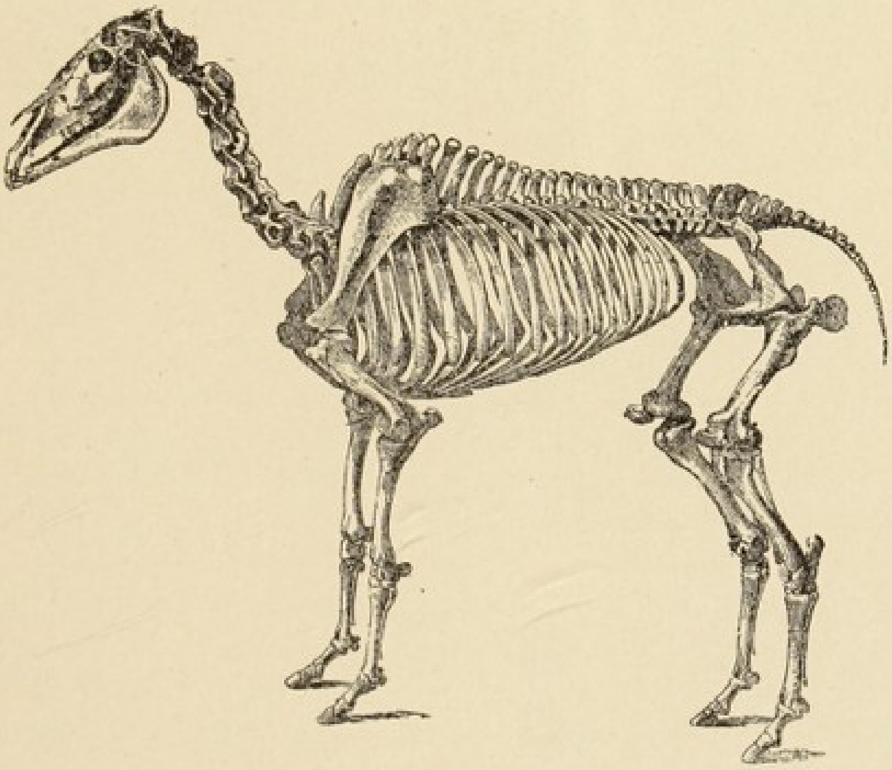
Rana catesbiana grows to a large size and may be found commonly with a body six inches long although often secured much larger.

FIG. 3



Skeleton of an alligator. (Kny-Scheerer Co.)

FIG. 4

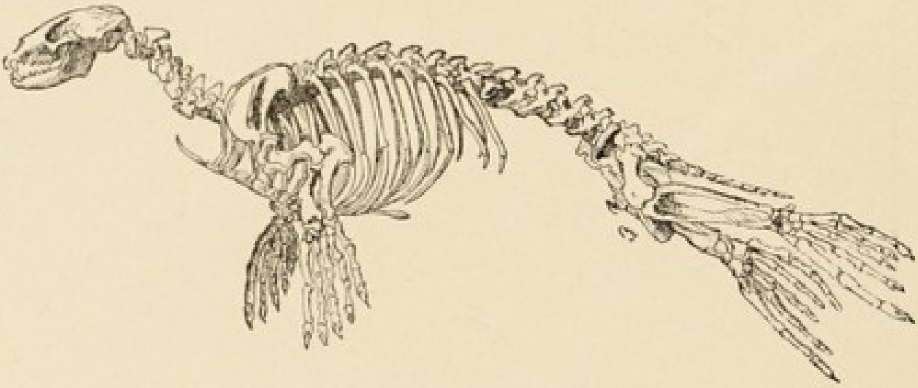


Skeleton of a horse. (Kny-Scheerer Co.)

They are quite abundant in many of the Adirondack ponds and their streams. In fact where they are abundant, the other frogs are absent, probably because being smaller, they are eaten by them. The bull frogs are usually found sitting partly buried in the soft mud or concealed by sticks or grass, when disturbed, they dive to the bottom and stir up the mud; then swim back to the edge of the water usually a foot or two from where they jumped. This habit and the color of their skin is their chief protection from snakes, mud turtles, fish, birds, etc., they are defenseless unless thus concealed. It is easy to catch them by dangling a hook variously baited in front of their noses. When this is moved slightly, it is usually jumped at although it may be held still against the nose for some time and be declined.

Their food is selected from insects, worms, decaying meat, tadpoles and small frogs. The front leg is used in pushing large objects into the mouth. All food is swallowed at once. The tongue is the chief organ used in securing small animals. It is thrown out and the passing insect is captured by the sticky secretion on its surface.

Fig. 5

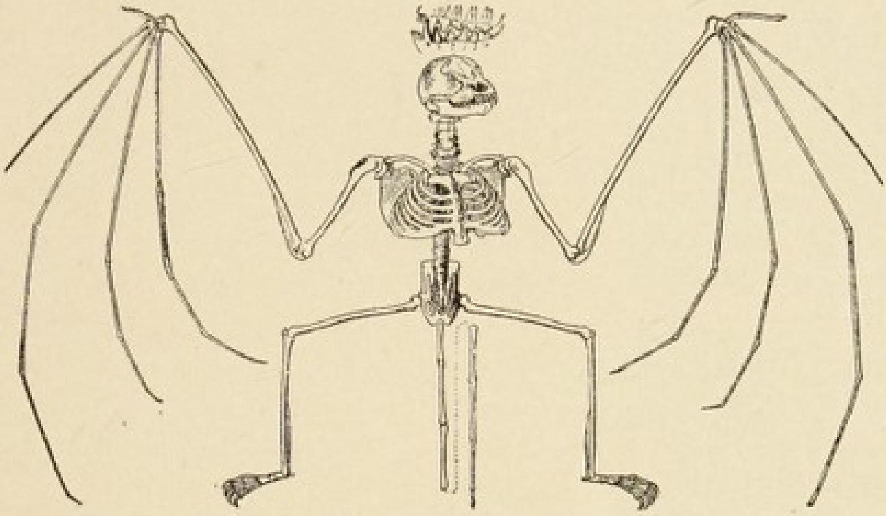


Skeleton of a seal. (Kny-Scheerer Co.)

The evening croaking of frogs, especially *Rana catesbiana* suggests that there is a sound producing organ and such is the case, for the sound results from forcing air past vocal cords. Vocal sacs in the side of the neck of the male act as resonators but are not capable of producing any sounds themselves. By holding a frog under water and gently rubbing it, croaking can be produced. The air comes out into the mouth and is then returned to the lungs as if it were just being breathed into the mouth, the air is thus used over and over in sound production.

The activities of the frog are largely regulated by the seasons. Its body temperature is about that of the surrounding medium in which it lives, it therefore varies from season to season. The term cold blooded is applied to fish, amphibia, and reptiles because of their low and varying bodily temperature. During the winter the frog hibernates in the mud below the frost line. The vital activities are greatly lessened, the lungs emptied (cutaneous respiration sufficing), mouth closed, the heart beats feebly and slowly. The energy

Fig. 6



Skeleton of a bat. (Kny-Scheerer Co.)

required to sustain this lowered vitality is taken in part from the muscles and accumulated fat. The tadpoles of *Rana catesbiana* usually spend the first winter as tadpoles changing into frogs during July and August of the following summer. They continue to grow for several years and may increase in size until ten years old.

References in Movement and the Nature of an Organism. Crampton. The Doctrine of Evolution, Chapter I. Jordan and Kellogg. Evolution and Animal Life, Chapter III. Rand. The Problem of Organization, *Science*, 1912, xxxvi, 803, No. 937. Schafer, E. A., The Nature, Origin, and Maintenance of Life, *Science*, 1912, xxxvi, 289, No. 923. Spencer, Principles of Biology. Verworn, General Physiology.

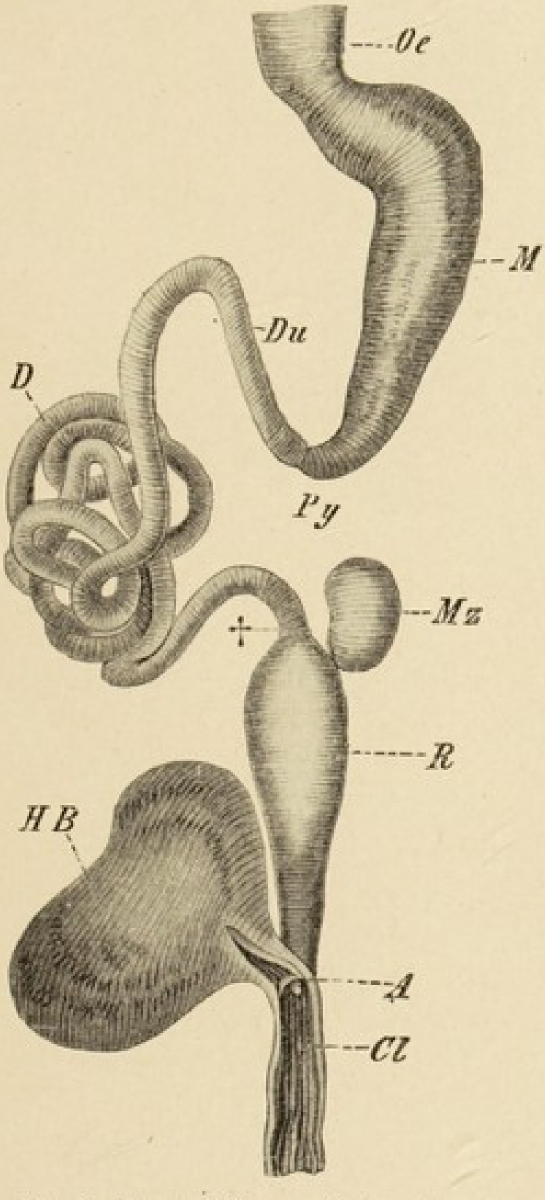
CHAPTER II

ORGAN SYSTEMS—SCOPE OF BIOLOGY

LABORATORY STUDY.—(*a*) Digestive organs of frog: Dissect mouth, esophagus, stomach, intestines, liver, bile duct, pancreas, and spleen; (*b*) lungs; (*c*) urinogenital organs. Work out the kidneys and their ducts, corpora adiposa, spermaries, ovaries, and oviducts.

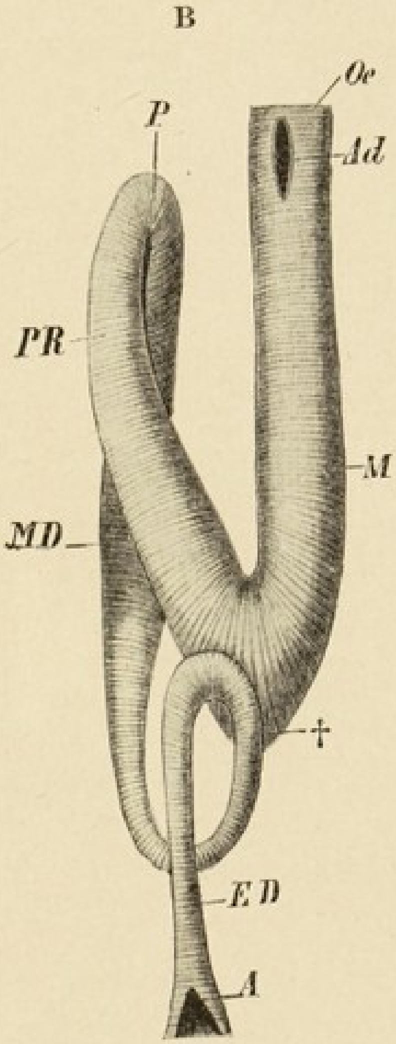
Digestive Canal.—The digestive organs of the frog consist of a hollow tube or canal and connected with it relatively solid glands. The digestive tube begins with the mouth and ends with the anal opening. The mouth is edged with lips and many short conical teeth on the upper jaw. The opening itself is relatively large compared with the size of the whole animal. This enables it to eat large tadpoles and small frogs, for the teeth are not used in tearing or grinding the food but rather assist in holding it when once seized. The tongue is attached at the tip of the lower jaw and is thrown out by the action of muscles forcing lymph into the tongue. On the roof of the mouth are found the vomerine teeth and beside them the internal nares. Near the angle of each jaw is the eustachian opening which passes into what corresponds to the middle ear. After the tympanic membrane is removed, the solid, single ear bone, the columella, is seen and the short passage into the mouth. The mouth cavity narrows in the posterior region but continues as a tube into a short distensible esophagus. Just in front of this opening is the glottis leading into the lungs. Each region of the digestive tube has a characteristic shape, this is particularly true of the stomach and an expert could readily isolate the correct drawing of a frog's stomach from that of any other vertebrate such as fish, snake, or man. The position, however, which it occupies in the body, its terminology, its cardiac and pyloric valves are the same as in all of the vertebrates. Passing from the spindle-shaped stomach, the intestine is small, coiled, and uniform in diameter until the large intestine is reached where it becomes much larger. A special name, cloaca, is given to the posterior region of the intestine because of its relation to the urinogenital organs which simply means that this region is used by both the digestive and urinogenital organs as a common passage to the exterior.

Fig. 7



Intestinal tract of *Rana esculenta*. *A*, opening of the large intestine into the cloaca (*cl*); *D*, small intestine; *Du*, duodenum; *HB*, urinary bladder; *Oe*, esophagus; *M*, stomach; *Mz*, spleen; *Py*, pyloric portion; *R*, large intestine. (After Wiederscheim.)

Fig. 8



Intestinal tract of *Amia*. *A*, anus; *Ad*, approach to the pneumatic duct; *ED*, end gut; *M*, stomach; *MD*, midgut; *Oe*, esophagus; *P*, region of the pyloric valve; *PR*, pyloric part of the stomach bent at †. (After Balfour and Parker, from Wiederscheim.)

Digestive Glands.—There are probably no digestive glands in the mouth other than those that secrete the viscid fluid used on the tongue. The large liver, covering most of the digestive organs, and the small pancreas are true digestive glands that discharge their secretions through a single duct into the anterior end of the

Fig. 9

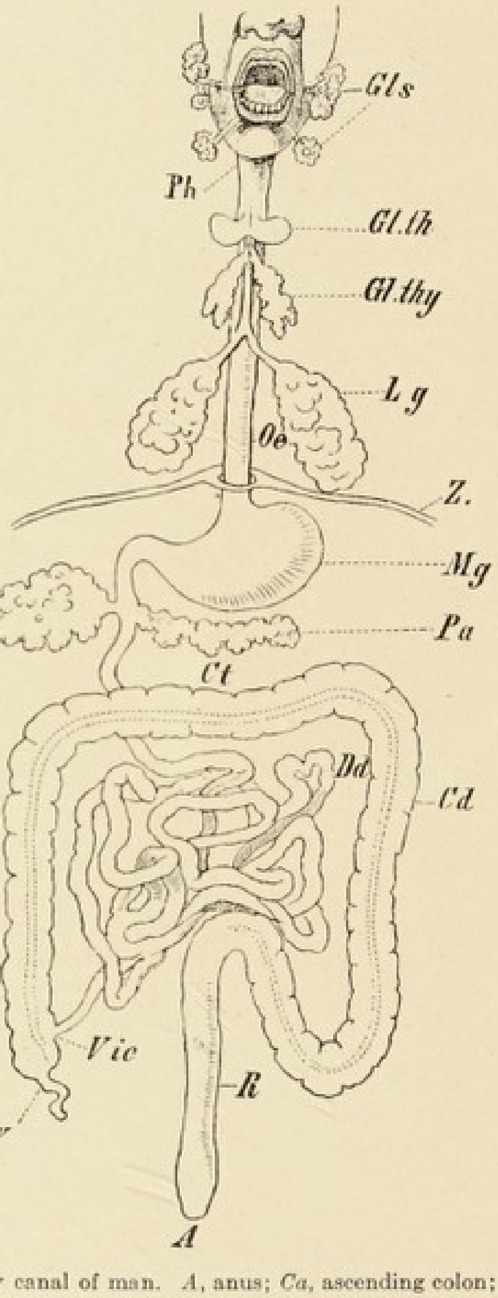
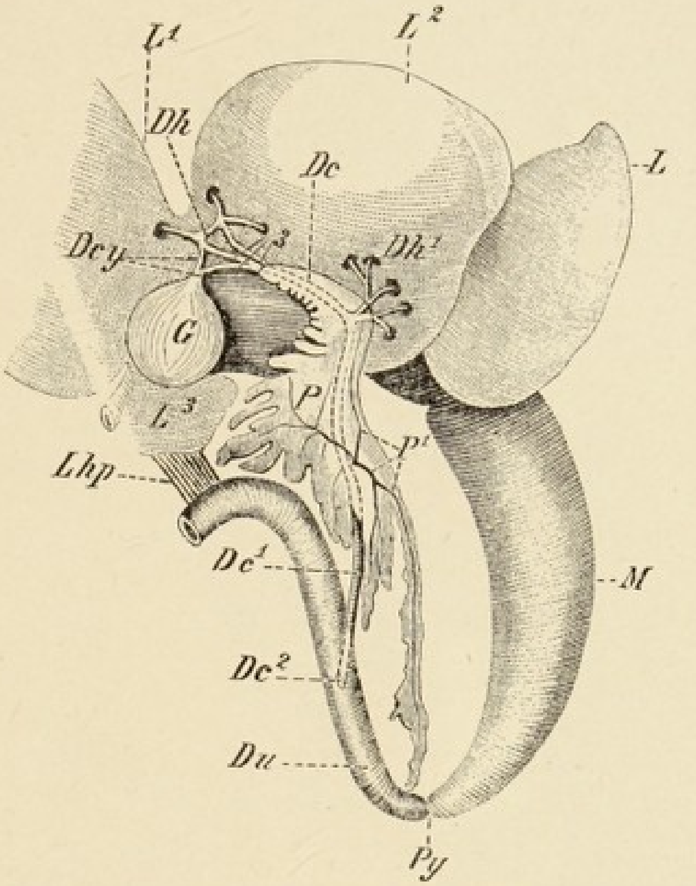


Diagram of the alimentary canal of man. *A*, anus; *Ca*, ascending colon; *Cd*, descending colon; *Ct*, transverse colon; *Dd*, small intestine; *Gls*, salivary glands; *Gl. th*, thyroid gland; *Gl. thy*, thymus gland; *Lb*, liver; *Lg*, lungs; *Mg*, stomach; *Oe*, esophagus; *Pa*, pancreas; *Ph*, pharynx; *Pv*, vermiform appendix; *R*, rectum; *Vic*, ileocolic valve; *Z*, diaphragm. (From Wiederscheim.)

intestines. Each gland as well as the intestine is held in place by a whitish, translucent membrane called mesentery that is attached to the back. On the mesentery of the small intestine is the small ductless gland, the spleen.

Fig. 10

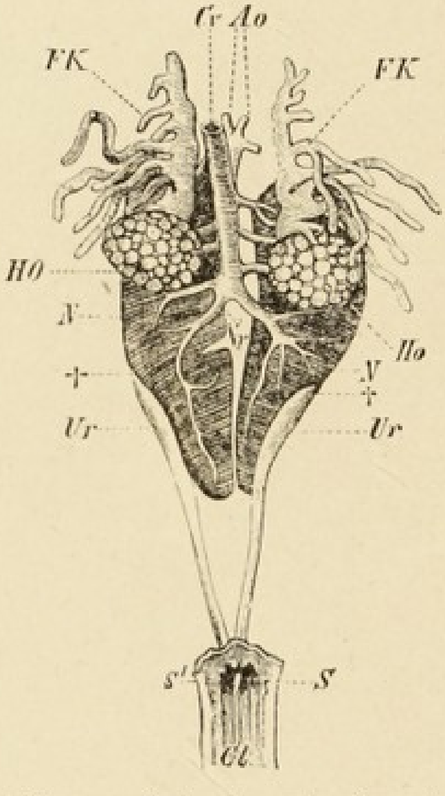


Pancreas and liver of *Rana esculenta*. *Dcy*, cystic ducts, which together with the hepatic ducts (*Dh*) form a network from which three collecting tubes arise, and these unite to form the common bile duct (*Dc*); the latter passes through the substance of the pancreas (*P*), receiving further hepatic ducts (Dh^1), and the pancreatic duct (P^1); at Dc^1 it becomes free from the pancreas, and passes back to open into the duodenum (*Du*) at Dc^2; *G*, gall-bladder; *L*, L^1, L^2, the lobes of the liver turned forward; *Lhp*, duodenohepatic omentum; *M*, stomach; *Py*, pyl (After Wiederscheim.)

Respiratory Organs.—The skin and lungs are the important respiratory organs. The lungs are capable of great distention and their inner area is about equal to $\frac{2}{3}$ of the total area of the skin. Experiments have shown that the frog can live when deprived of the use of either the skin or the lungs in carrying on the work of respiration. That this work of respiration can be carried on by two very different organs serves well to illustrate the principle of respiration. The essential structure in this process is a membrane which occurs between the air and blood. Respiration is simply defined as "air passing through a membrane." The oxygen of the air may thus pass through the skin or lungs into the blood. This portion of the process is external respiration. The blood carries this oxygen to all parts of the body receiving in the meantime varying amounts of carbon dioxide. The giving up of the oxygen to all parts of the body is called internal respiration.

Urinogenital Organs.—It is customary to discuss these two sets of organs under one caption because of their intimate structural connections in the male. The small red kidneys are similar in the male

Fig. 11



Male urinogenital organs of *Rana esculenta*. *Ao*, aorta; *Cv*, postcaval vein; *FK*, corpus adiposum; *Ho*, testis; *S*, *S*[1], apertures into cloaca (*cl*) of *Ur*, urinogenital ducts; *Ur*, renal veins. (After Wiederscheim.)

and female frog. A short ureter in the female carries the urea from the kidney to the cloaca. From the cloaca the urea passes by gravity into the ventral bi-lobed bladder. The ovaries are usually very large, irregular organs surrounded by a thin membrane and attached to the back. There is no opening or duct leading from them. When the time arrives for the discharge of the eggs, they are set free in the body cavity through many openings in the wall of the ovary. The long coiled oviducts are separate from the ovaries and from each other, each has a wide opening just dorsal to the stomach into which (so far as we know) the eggs are forced by the general bodily movements. The posterior end of the oviduct is enlarged to act as a receptacle for the eggs just prior to egg laying. The oviduct empties

Fig. 12

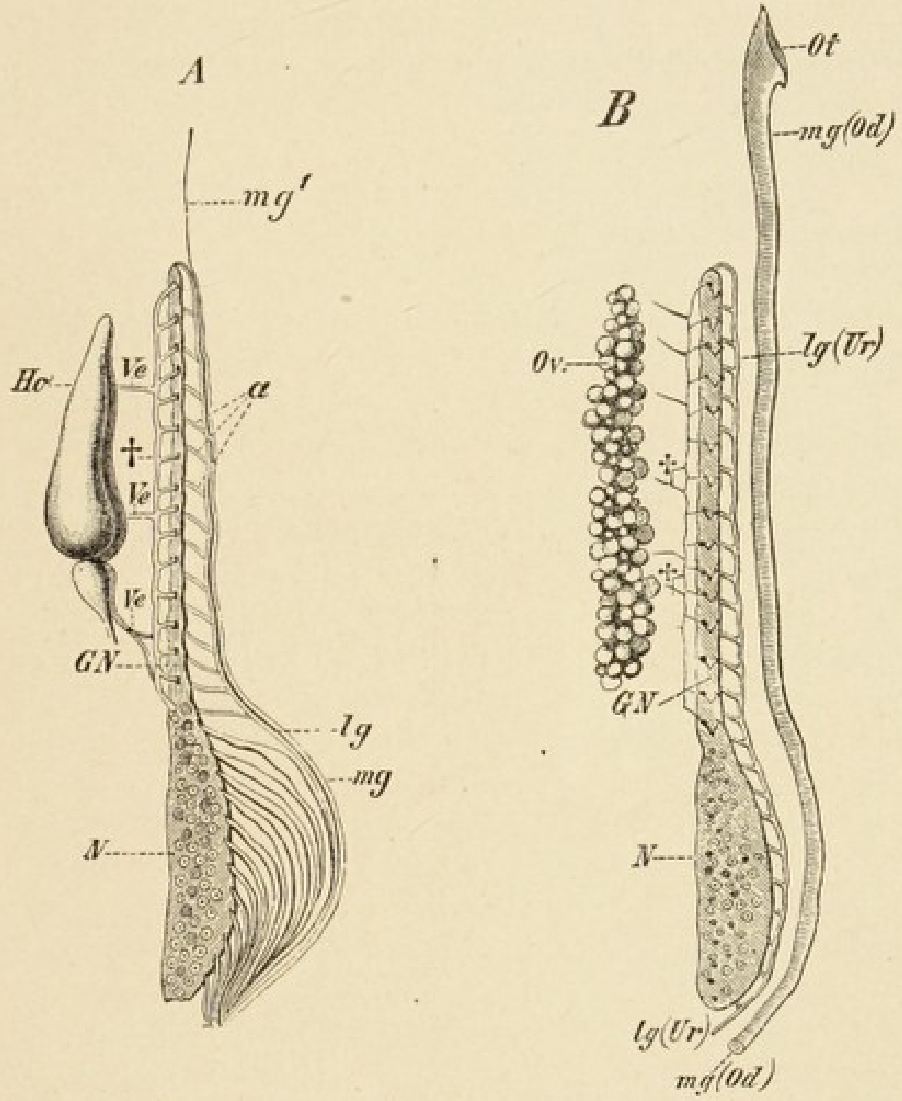


Diagram of the urinogenital system of (*A*) male and (*B*) female *Urodele*. *a*, collecting tubules of kidney which open into the urinogenital duct (*lg*); in the female the latter serves simply as the urinary duct (*Ur*), and the system of *Vasa efferentia* is vestigial; *GN*, anterior portion of kidney; *Ho*, testis; *mg*. *mg*[1], rudimentary oviduct; *N*, posterior non-sexual portion of kidney; *Ot*, anterior end and opening of oviduct (*Od*); *Ov*, ovary; *Ve*, vasa efferentia of testis. (After Spengel, from Wiederscheim.)

into the cloaca. In the male the parts are more closely united. The small spermary is supported by a mesentery that holds it near the anterior end of the kidney. Through this mesentery pass a number of minute tubes that carry the sperms into the kidney.

After the sperms reach the kidney, they pass through and escape into the cloaca by using the regular duct of the kidney, the ureter. The ureter of the male becomes enlarged near the posterior end for the reception of sperms. Because this duct carries both urea and sperms, it is called the urinogenital duct. Critical dissection usually reveals the presence of a small coiled structure just outside of the urinogenital duct which can be traced anterior to each kidney when it becomes minute. This is a rudimentary structure, *i. e.*, one that was of use to some ancestor of the frogs but not now used. If the large oviducts of the female frog were greatly reduced in size, they would look just like these structures in the male frog which are designated rudimentary oviducts. There are many cases on record in the frog of finding small ovaries variously associated with the spermaries. The rudimentary oviducts and the occasional presence of partly developed ovaries suggest that the ancestors of the frogs were hermaphroditic, *i. e.*, possessed both spermaries and ovaries. Attached to the anterior end of each kidney are the corpora adiposa which do not decrease in size until the period when the frog begins to grow eggs or sperms.

Cœlom.—All of these organs are located in a large cavity which is termed the cœlom. It is on the ventral side of the body and is a common cavity in all vertebrates.

Organ Systems.—In any description of a set of organs to which a single name can be given certain intimate relations are implied. While there are many different parts which may have widely different shapes, they all work in harmony to produce some single purpose as the digestive organs in digesting food, etc. Here each organ does a given part of the whole work. The work is thus done better than if there were no such division into organs. This using of many organs in carrying out a single general work of an organism is characteristic of all complex plants and animals, and results in a system of organs. Each system of organs assumes a given work for the benefit of the organism so that it is often described under the heading of physiological division of labor. This same principle describes accurately the difference between a complex civilization where most people are experts, that is, they do some one thing well, from that of barbarians where each does many things and these but indifferently. In the former case each is dependent upon many others for existence; while in the latter a single family often sustains existence and provides for all of its own wants. The frog would soon die, if any of the organs were permanently removed from any of its organ systems. It would be likewise difficult for us to exist if those who supplied us with certain articles ceased to exist.

Scope of Biology.—Biology aims to ask four general questions: (1) What is it? (2) What does it do? (3) How does it arise? (4) How did it come to have its present form and relations? Each of these questions leads into rather well defined lines of study. The discussion thus far has centred mainly around the first question. This study of the shape, structure and relation of parts, is known by the technical term of morphology; while the answer to the second question seeks to know of the work of these parts and is called likewise by a special term, physiology. A suitable answer to the third question involves the study of how each single organism comes into existence and grows into a mature organism and this branch of biology is called embryology. The fourth question is more general and comprehensive, for it includes the history of the frog family, and must needs consider the record left in the rocks as well as all of historic time and the relation of its environment as an influence on the development of the frog family. This phase of biology is called evolution. Every organism may be studied from these four points of view, but these are very general terms and the science of biology has made marvelous progress so that each of these great subdivisions is again divided into special departments of biological learning, a mere statement of which will suffice.

Biology	1. Morphology	Anthropology Anatomy Histology Taxonomy	Applied to medicine, forestry, agriculture.
	2. Physiology	Physiology general and human disease Psychology Sociology	
	3. Embryology		
	4. Evolution	Heredity Variation Distribution Racial history	

CHAPTER III

PHYSIOLOGY OF DIGESTION IN THE FROG

LABORATORY STUDY. Foods.—Proteins, carbohydrates, and fats. Distinguish by the usual tests and make several digestion experiments. Make an osmometer for the food tests.

Need of Food.—While the frog cannot tell us in words that he requires food yet we are as certain that he does as if he could say, "I am hungry." In fact that is just what his actions mean when we make him jump along the bank after a baited hook. Because the frog is an animal and because man is an animal in just the same sense, we are justified in using many things that we know about man in our attempt to explain the work of the various organs of the frog. In this sense the chapter heading might read the "physiology of digestion of an animal."

The need for food is fundamental with all living things because they all use energy in living and energy is something that is not created but exists all of the time in one form or another. The frog as a typical animal, shows the relation of this energy as it exists in the form of food. The frog expends energy in three conspicuous ways: (1) In every movement of the body there is an expenditure of energy in the contraction of the muscles. The frog can be made to jump continuously for a time but soon the jump grows short and it takes a stronger stimulus to cause it, after a little longer time the frog refuses to jump, the muscles are, so far as general observation goes, just the same as when the first jump was made but after this severe muscular exertion there is a condition of exhaustion until the muscles can be supplied with more food. It is well known that the simple elements which unite to make proteins or carbohydrates do not act as a food when fed to the frog but that they must be combined into one of the three classes of foods. This can only mean that some definite agency has been at work to combine the many chemical elements found in the foods. In this respect the frog is like all other animals in requiring that its food be ready-made as it has no power to manufacture food out of the raw chemical elements. (2) The need for food arises because of the periodic production of a large number of eggs by the female and many sperms by the male. Both eggs and sperms are living and as such have been grown. The production of the living germinal substance especially the egg utilizes a large amount of energy that is indirectly supplied by the food eaten. (3) The body of the frog while in a large measure subject to the surrounding temperature, does utilize, to some extent, energy in the production of heat. This keeping the body warm is a more conspicuous expenditure of energy in birds and mammals where a constant bodily temperature is maintained.

Unless the frog can meet these three needs of the body it soon dies; that these three needs are supplied, there is abundant evidence. The laboratory study showed that foods are commonly divided into proteins, carbohydrates, and fats, to these three must be added water and certain salts which are either taken separately or as a part of the foods.

Proteins.—Proteins are complex compounds which always contain carbon, hydrogen, nitrogen, oxygen and usually sulphur and phosphorous. These several chemical elements usually exist in about the following percentages: Nitrogen, 16 per cent.; carbon, 52 per cent.; hydrogen, 7 per cent.; oxygen, 23 per cent.; sodium, 2 to 5 per cent. and a trace of potassium bromide. The frog secures his protein from the flesh that he eats, as all lean meat belongs to this class of foods. As the frog is not very particular in the selection of his food, he may get some plant proteins. Proteins are non-diffusible, are coagulated by heat and are usually called nitrogenous foods. Explaining their use to the frog in terms of what is known about higher animals, it can be said that proteins serve the definite work of renewing all of the worn out and exhausted parts of the organs. In fact no other kind of food can do just this work nor does any other class of food stand in such close relation to the vital processes of the frog. Oxygen, nitrogen, and all of the other elements exist in the air but they cannot be used in the repair of the organs because they are not combined into protein molecules.

Carbohydrates.—Carbohydrates contain carbon, hydrogen, and oxygen; with the hydrogen and oxygen combined in the same proportions as water, H_2O, this is shown in the starch molecule, $C_6H_{10}O_5$, where one may expect to find about 44.4 per cent. of carbon, 6.2 per cent. of hydrogen, and 49.4 per cent. of oxygen.

Fats.—Fats are formed of the same elements as carbohydrates but there is less oxygen in the fat molecule. Because of the absence of nitrogen, these last two classes of foods are called non-nitrogenous foods. Fats contain about the following proportions: Carbon, 76.5 per cent.; hydrogen, 11.9 per cent.; oxygen, 11.5 per cent. The non-nitrogenous foods are easily diffusible and serve as the natural fuel foodstuffs of the body. They cannot serve for renewing the exhausted parts of an organism. The frog does not secure a large amount of carbohydrate except as vegetable matter is eaten, but it does get plenty of fat associated with the lean meat of insects, tadpoles, frogs, etc.

Digestion.—It is easily recognized that the food of the frog after it has been eaten is not within his body proper but simply in the hollow digestive tube. It is entirely possible for food to pass through the frog and not yield any energy simply because it has not entered into the body of the frog. Most of the foods have to undergo important changes before they pass through the walls of the digestive tube. These changes are induced by what are called digestive secretions. A secretion is defined in biology as follows: Any substance which is the product of living cells and serves some useful purpose in the economy of the organism may be called a secretion. In this sense every secretion has been a part of the living substance of some part of an organism and is usually produced in what are known as glands such as the liver or pancreas, in other instances the gland is a small part of the inner wall of the stomach. The ovaries and spermaries are both glands although their secretion takes the form of cells, ova, and sperms, instead of a fluid. The digestive secretions are known as enzymes because of the nature of the changes that they are capable of producing in the food. The term enzyme or the more common term ferment is difficult to explain. Fischer speaks of the specific action of enzymes, that is, the capacity of digestive ferments to attack one substance and not another which may even be closely related. Halliburton illustrates the work of a ferment by saying: "We may roughly compare enzyme to an ill-disposed person who comes into a room full of good-natured people and who succeeds in setting them all by the ears. He has produced a change in them without undergoing any change himself by his mere presence. He is, moreover, able to repeat the process over and over again in fresh roomfuls *ad infinitum*."

The stomach of the frog contains many glands that produce gastric juice which consists of a small amount of hydrochloric acid and the enzyme, pepsin. Pepsin acts on the proteins only and transforms them into a substance that will pass through the walls of the digestive tube. It is difficult to understand how this change is brought about and especially the extent of the changes which take place in the protein molecule for the pepsin is the same as when it was set free from the glands and poured into the stomach, but the molecule of protein has undergone a great change the details of which are too technical for this work. The action of an enzyme on a food is known as fermentation and since pepsin acts just as readily in a test-tube as in the stomach, *i. e.*, apart from the living gland that produced it, it is called an unorganized or non-living ferment. All of the digestive ferments are unorganized.

When the gastric enzyme has done its work, the residue of undigested proteins, the fats and the carbohydrates pass into the intestine to come in contact with the secretions of the liver and pancreas where the process of digestion is completed, the principle of which is the same as described for the stomach, the general effect of which is to bring foodstuffs into solution and a soluble form.

The digested food is absorbed through the walls of the digestive tube and passes into the blood where its course will be followed in the next chapter. The use of the word absorb does not convey an accurate idea of just what is meant by the process. In this passing of food through an animal membrane, the digestive walls, there is the physical process of osmosis to which must be added probably some action on the part of the living wall of the digestive tube. Just what this action is cannot be fully stated.

The fate of the digestive secretions illustrates one of the strange wastes of Nature. After the several foods have been rendered soluble and diffusible, in other words, digested, we are led to believe that there is just as much of the several enzymes as when the digestive process began. The body of the frog does not absorb them so they pass from the body with the indigestible parts of the food. If Nature provided some way of collecting and using over these secretions, there would be a large economy in the life of every animal. The need for food and the principles by which it is digested are common to all forms of life.

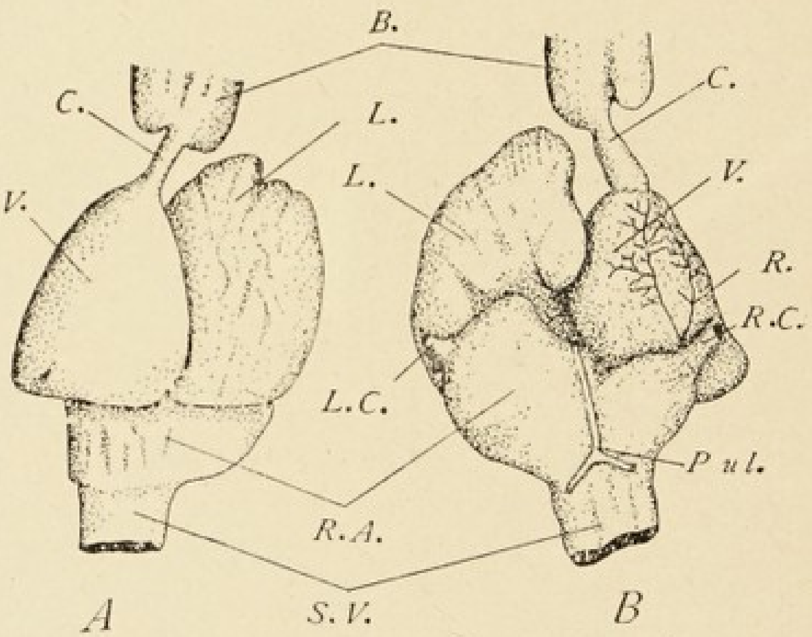
CHAPTER IV

CIRCULATION—METABOLISM

Laboratory Study.—Study the circulatory organs; work out parts of the heart and distribution of main arteries of frog. Study blood corpuscles and capillaries in web of frog's foot or other suitable place in tadpole.

Heart.—The blood of the frog follows well defined routes as it travels to all parts of the body, and in this particular the frog belongs to the higher rather than to the lower class of animals. These routes

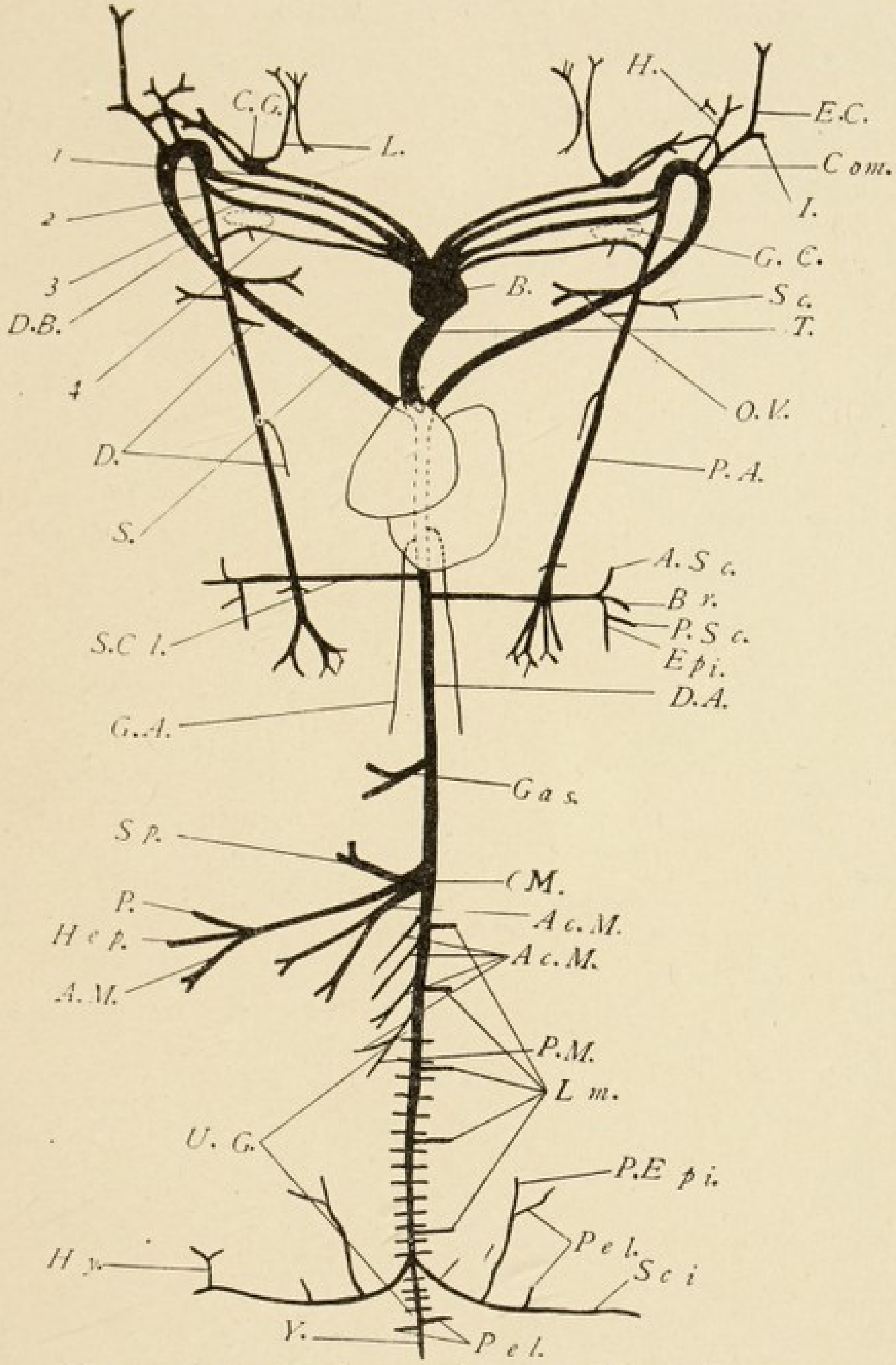
Fig. 13



The heart of *Cryptobranchus*. *A*, ventral; *B*, dorsal aspect. *B*, bulbus arteriosus; *C*, conu; arteriosus; *L*, left auricle; *L.C.*, left anterior vena cava; *Pul.*, pulmonary; *R*, coronary vesselss *R.C.*, right anterior vena cava; *S.V.*, sinus venosus; *V.*, ventricle. (Reese.)

of travel for the blood are the arteries which carry it from the heart and the veins which return it to the heart. The heart is a most interesting organ because of its origin and work. Could you observe the heart as it first begins to beat and force blood along in the embryonic bloodvessels, you would not recognize in it the adult, conical, compact heart but rather an elongated branched structure which passes through a series of complicated changes before the adult

Fig. 14



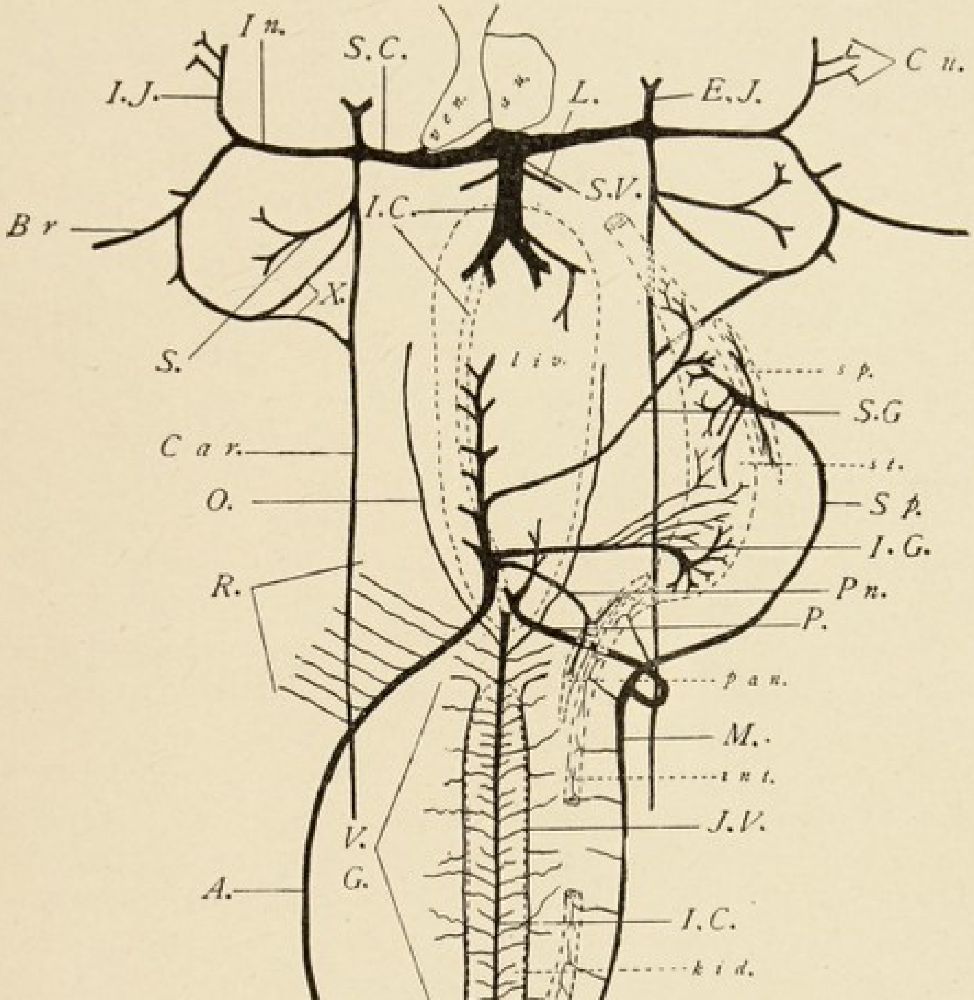
The arterial system of *Cryptobranchus*, ventral aspect. *A.M.*, anterior mesenteric; *Ac.M.*, accessory mesenteric; *A. Sc.*, anterior scapular; *B.*, bulbus arteriosus; *Br.*, brachial; *C.G.*, carotid gland; *C.M.*, celiacomesenteric; *Com.*, ramus communicans; *D.*, to dorsal region near lungs; *D.A.*, dorsal aorta; *D.B.*, ductus Botalli; *E.C.*, external carotid; *Epi.*, epigastric; *G.A.*, anterior genitals; *Gas.*, gastric; *G.C.*, gill cleft; *H.*, hyoid; *Hep.*, hepatic; *Hy.*, hypogastric; *I.*, internal carotid; *L.*, lingual; *Lm.*, lumbar; *O.V.*, occipitovertebral; *P.*, pancreatic; *P.A.*, pulmonary; *Pel.*, pelvic; *P.Epi.*, posterior epigastric; *P.M.*, posterior mesenteric; *P.Sc.*, posterior scapular; *Sc.*, scapular; *Sci.*, sciatic; *S.Cl.*, subclavian; *Sp.*, splenic; *T.*, conus arteriosus; *U.G.*, urogenitals; *Y.*, caudal; 1, 2, 3, 4, first to fourth branchial arches. (Reese.)

structure is reached. This wonderful propelling organ for the blood is a gradual growth and it took Nature a long time to evolve it. The work of the heart is to force the blood continually through the bloodvessels. It contracts slowly as compared with the human heart, but evenly and uniformly during the active season; while during hibernation the beats are feeble and slow. The fact that a structure has been produced which will work regularly day and night, week after week, year after year, and only rest seconds or fractions of a second at a time is a constant source of wonder.

Blood.—The blood which enters the left auricle from the lungs and the blood which enters the right auricle from the veins is poured into the single ventricle so that there is not a complete separation of pure and impure blood such as characterizes birds and mammals. The blood of the frog consists of corpuscles and plasma. There are three kinds of corpuscles: (1) The red, which are oval in outline and contain hemoglobin. The work of the hemoglobin is to carry the oxygen from the organs of respiration to all parts of the body. (2) The white corpuscles, smaller than the red and irregular in shape. They are factors in the clotting of blood, the destruction of foreign bodies such as disease germs, and the removal of degenerating parts. (3) The spindle shaped corpuscles which are colorless except during the spring when they acquire hemoglobin and are transformed into red blood corpuscles. They are smaller than the red corpuscles and may change their shape somewhat. Besides forming new red cells, they assist in the clotting of the blood. The blood corpuscles wear out like the other parts of the body and have to be renewed. The marrow of the bones is one of the most important sources for the origin of new blood corpuscles. The plasma of the blood is straw colored or else colorless in appearance. It contains the various transformed foods, water, salts, as well as the waste products of the body; hence its chemical composition varies from day to day and season to season, being influenced largely by the amount of activity and the food supply.

Respiration.—The carrying of food to all parts of the body is but one work which the blood does. A second is its relation to respiration; the presence of hemoglobin in the red blood corpuscles is for the sole purpose of uniting chemically with the oxygen as the blood flows through the lungs or close to the skin. The oxygen becomes loosely combined with the hemoglobin with which it remains until a place in the body is reached where there is a scarcity of oxygen, then the oxygen is released from the hemoglobin to pass through the walls of the capillaries and become a part of the living substances or to take part in the vital activities of that region. Coincident with the taking of oxygen to the parts deficient in oxygen, is the carrying away from these same regions a waste substance known

Fig. 15



The venous system of *Cryptobranchus*, ventral aspect. *A.*, abdominal; *Br.*, brachial; *C.*, caudal; *Car.*, posterior cardinal; *Cu.*, cutaneous; *E.J.*, external jugular; *G.*, genital; *I.C.*, inferior cava; *I.G.*, inferior gastric; *I.J.*, internal jugular; *Il.*, iliac; *In.*, innominate; *J.V.*, vein of Jacobson; *L*, pulmonary; *M.*, mesenteric; *O*, oviduct; *P.*, portal; *Pn.*, pancreatic; *R.*, parietals; *S.C.*, superior vena cava; *S.*, from shoulder; *Sp.*, splenic; *S.V.*, sinus venosus; *V.*, vertebral; *Vs.*, from urinary bladder; *X.*, plexus. (Reese.)

as carbon dioxide, this waste substance arises as one of the products of the expenditure of energy by the frog. The carbon dioxide is carried to the lungs or skin where it leaves the body of the frog to pass into the air. The frog then is continually taking oxygen from the air and giving off a waste substance, carbon dioxide, to the air. If certain other agencies were not at work, we could easily believe that after a time the oxygen content of the air would become so much reduced that breathing for all animals would become difficult or impossible. In applying the term waste to carbon dioxide a definite meaning is given in biology. Waste substances are such as have once been a part of the living body and are produced as a result of some expenditure by the living organism. In this sense waste and excretion have the same meaning.

Metabolism.—The nature of the several excretions and the character of the food in the blood tell much concerning the vital processes. More can be learned in an advanced course in physiology, but even there a great deal is not understood. There seem to be a number of constructive or up-building agencies in the form of internal enzymes which serve to make the combinations of the nitrogenous and non-nitrogenous molecules more like those that exist in living substance, but there is still a wide difference between the two and science has not yet discovered just how the food becomes living. How long the transformed food remains a part of the living substance is a matter of conjecture. The changes which initiate the breaking down of the living substance and the formation of waste products are also unknown; yet the two processes are taking place all of the time in the body of the frog, the one in the nature of constructive or up-building, the other destructive or tearing down. To cover these two widely different processes in the body, the general term of metabolism is used. "Metabolism designates that complex of chemical changes in living organisms which constitute their life, the changes by which their food is assimilated and becomes a part of them, the changes which it undergoes while it shares their life, and finally those by which it is returned to the condition of inanimate matter. Gathered together under this one phrase are some of the most intricate and inaccessible of natural phenomena." (Chittenden.) The single word metabolism is used to indicate one of the distinguishing characters of all organisms. In using the term in this way it is understood to include the changes indicated in the definition; and while these are many and divergent, yet they are a part of one vital process. Thus used metabolism serves to mark off sharply the activities of living substance from all forms of activity in non-living matter and is a distinguishing feature of living matter only.

CHAPTER V

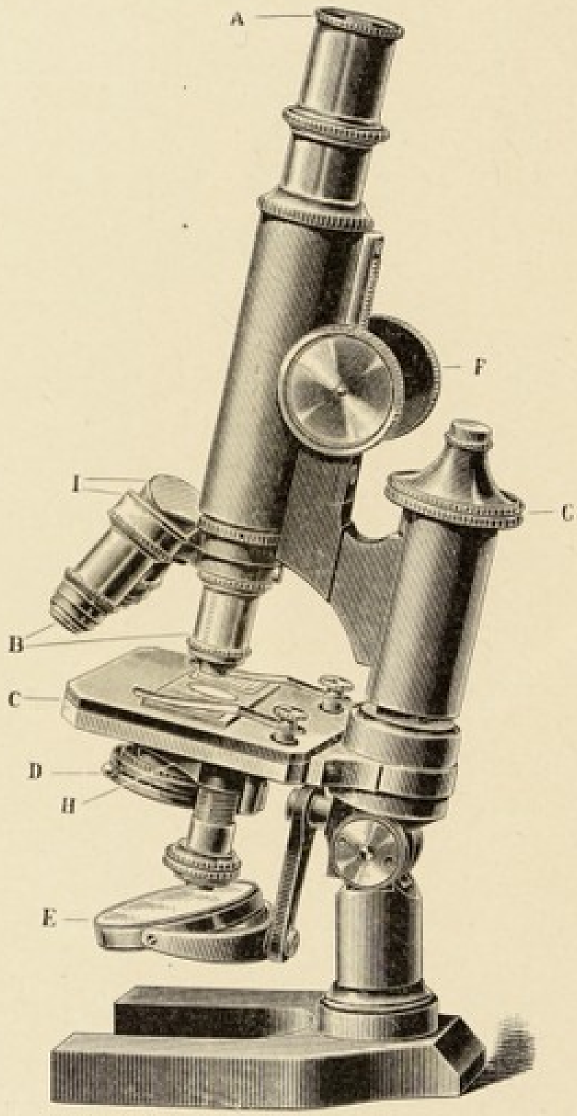
TISSUES AND CELLS

LABORATORY STUDY.—Parts of the microscope and their use. Histology of the cross-section of the intestine or stomach of the frog.

Histology.—Anatomy or gross morphology enables one to learn much about the shape and relations of most of the organs of the frog but it tells very little about the parts of the organs themselves. In the analysis of the minute structure of an organ the method is essentially the same as in the study of anatomy except that one must employ some magnifying instrument to enlarge the minute parts in the organ. The compound microscope is used for this purpose. The preparation of an organ for this minute analysis illustrates how biology utilizes the science of chemistry, for without the chemical information now available the details of an organ as well as many other important biological facts would be unknown. The general term histology is used for both the preparation of an organ and its subsequent analysis by the aid of the microscope. In the preparation of the organ for histological study several distinct chemical processess are employed usually in the following order: (1) Killing and fixing all of the parts of the organ in as normal a relation and shape as possible. (2) Hardening the many parts so that they will retain their characteritsic outline, etc. (3) The staining of all of the parts so as to differentiate them as a result of their different reactions to stain. It requires much skill to be able to secure the best possible results in the use of the many stains now employed. (4) The parts of the organ must be cut into thin nearly transparent sections, if the microscope is to be employed in studying them. Each of these several steps requires much detailed technical work, each step of which must be accurately done or the result is a failure. The science of histology is very technical although fundamental to the study of embryology, pathology, and bacteriology. The present chapter aims to serve as an introduction to the histological analysis of an organ.

Histology of Intestine or Stomach.—When the microscopic slide of the stomach or intestine was studied, it was an easy task to recognize three general layers. Each layer was characterized by having many very small structures known as cells. These cells in the inner layer were elongated and arranged in rows. In a similar manner, the shape and arrangement of the cells in the other layers

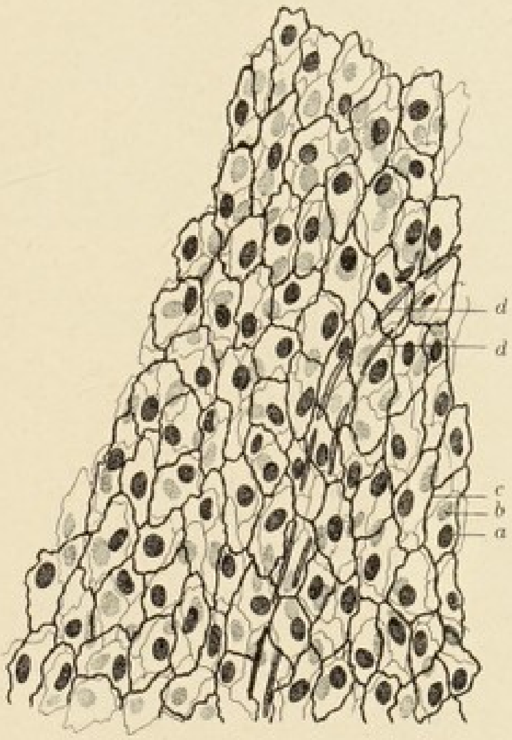
FIG. 16



Compound microscope. *A*, ocular or eye-piece; *B*, objective; *C*, stage; *D*, iris diaphragm, *E*, reflector; *F*, coarse adjustment; *G*, fine adjustment; *H*, substage condensing apparatus; *I*, nose-piece. (Abbott.)

were made out. These different layers are known as tissues and from a morphological standpoint a tissue is defined as a group of similar cells, similar in shape and arrangement; but this is only part of the definition, for these similar cells must do a similar work for the organ. A tissue is, therefore, usually defined as a group of similar cells having a similar function. The definition should always be recognized as having these two aspects. All of the organs of the frog are made up of several tissues, and what is true of the frog is true of all complex animals so that an organ is defined as a group of tissues united in order to do a given work for the organism.

Fig. 17



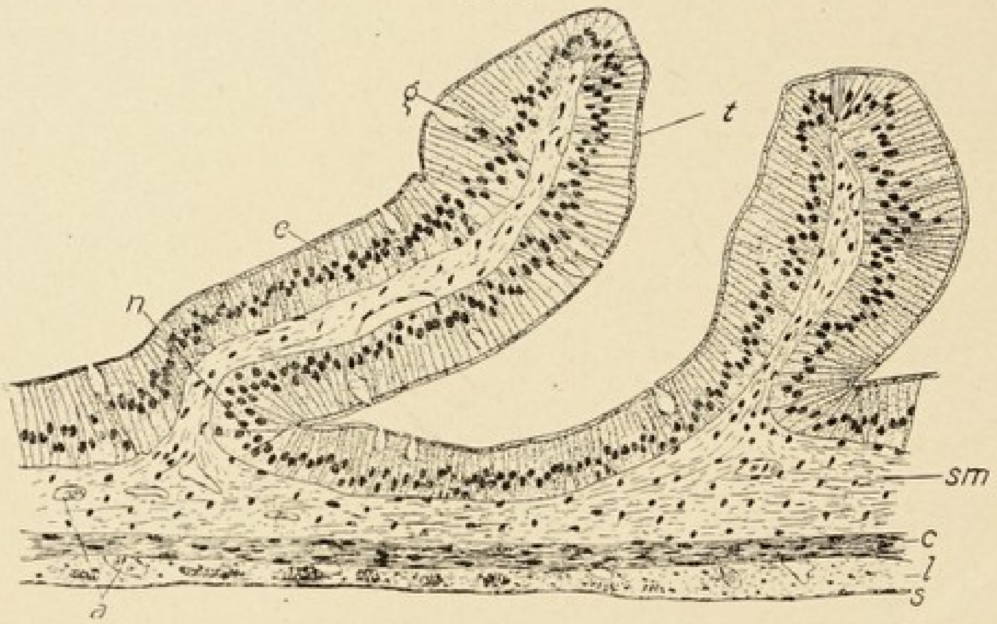
Mesentery of frog treated with silver nitrate. The mesentery is covered on both surfaces with a layer of endothelium. Between these is areolar connective tissue containing bloodvessels, lymphatics, and nerves. In this figure only the two endothelial layers and a capillary bloodvessel are represented: *a*, nucleus of endothelial cell belonging to uppermost layer; *b*, nucleus of cell belonging to deep layer forming the lower surface of the specimen; *c*, intracellular cement between cells of upper layer of endothelium; *d*, *d*, nuclei of endothelial cells, forming a capillary bloodvessel, seen in profile. The bodies of these cells are not reproduced in the figure. The cement in the deep layer of endothelium is represented by finer lines to distinguish it from that belonging to the upper layer. (Dunham.)

Tissues.—The body of all the higher organisms consists of a number of distinct tissues which have been arranged into four classes based on their function and intimate structure. These are (1) epithelial; (2) connective or supporting; (3) muscular; (4) nervous.

1. *Epithelial Tissues.*—The epithelial tissues are the oldest and the first to appear in the embryonic development. They have undergone but little modification in order to perform their several functions. Their most important work is to form a protective

covering to surfaces, both exterior and interior. Their very position makes them the most important structures in secretion and excre-

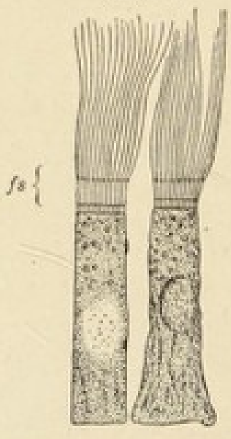
Fig. 18



Transverse section through the intestinal wall of *Cryptobranchus* to show the details of two longitudinal folds. *a*, bloodvessels; *c*, circular muscle layer; *e*, columnar epithelium forming the layer; *g*, goblet cells; *l*, longitudinal muscle layer; *n*, group of young cells; *s*, serosa; *sm*, submucosa; *t*, top-plate or striated border. (Reese.)

tion; and in receiving stimuli from the external world, hence epithelial tissue is subdivided into (*a*) flattened or squamose; (*b*) columnar;

Fig. 19



Ciliated epithelium. Columnar cells. (Frenzel.)

(*c*) ciliated. Epithelial tissue has a small amount of intercellular substance. The reproductive cells are modified epithelial tissue.

2. *Connective Tissues.*—Connective tissues embrace a large number of tissues whose main function is to bind the parts of the organism together. They are found in the deep parts of the body,

Fig. 20

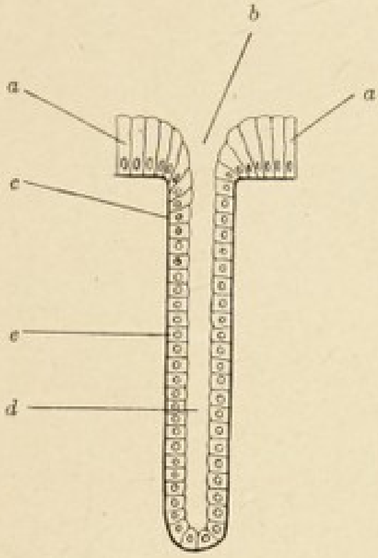


Fig. 21

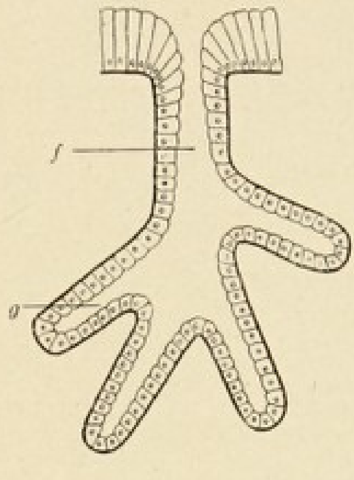


Fig. 22

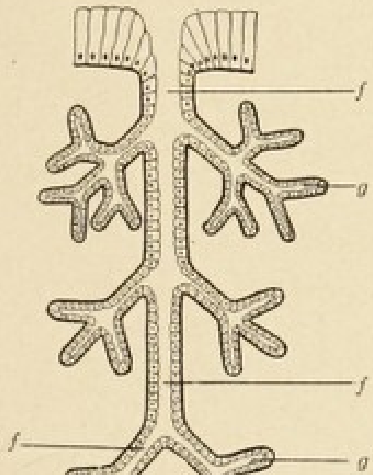
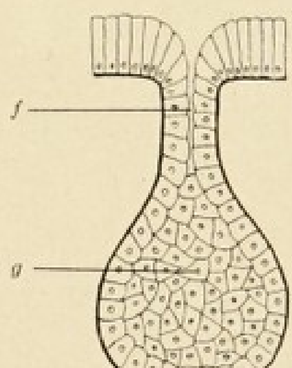


Fig. 23



Diagrams representing various types of gland. (Dunham.)

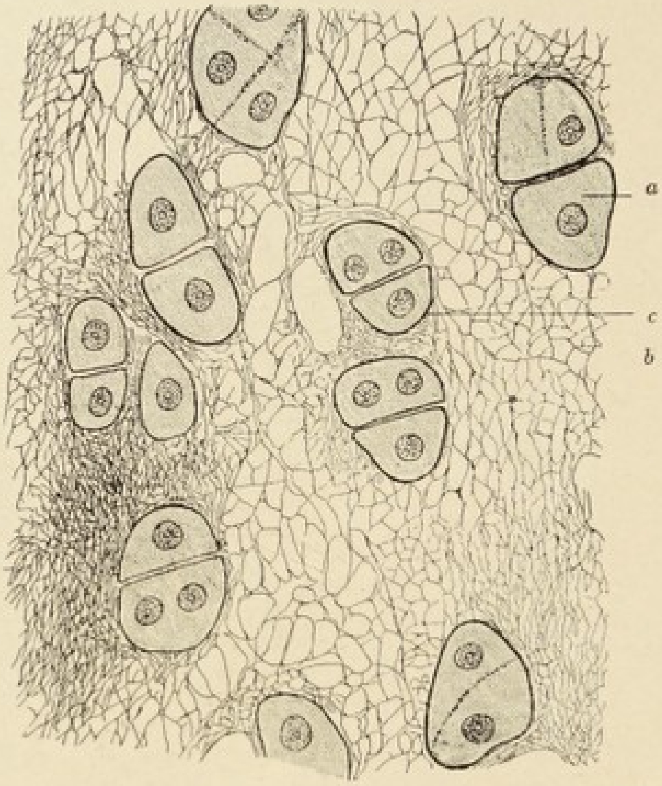
Fig. 20.—Simple tubular gland. *a*, epithelium covering the surface on which the secretion is discharged; *b*, mouth of gland; *c*, epithelium lining the duct. This gradually passes into the secreting epithelium. Some simple tubular glands have no such distinction between the cells near the mouth and those nearer the fundus, but all the cells are of the secreting variety, *i. e.*, exercise that function; *e*, secretory epithelium; *d*, lumen. The sweat glands are simple tubular glands which are coiled in their lower part to form a globular mass.

Fig. 21.—Compound tubular gland: *f*, duct; *g*, acinus.

Fig. 22.—Racemose tubular gland: *f*, *f*, *f*, ducts; *g*, *g*, acini.

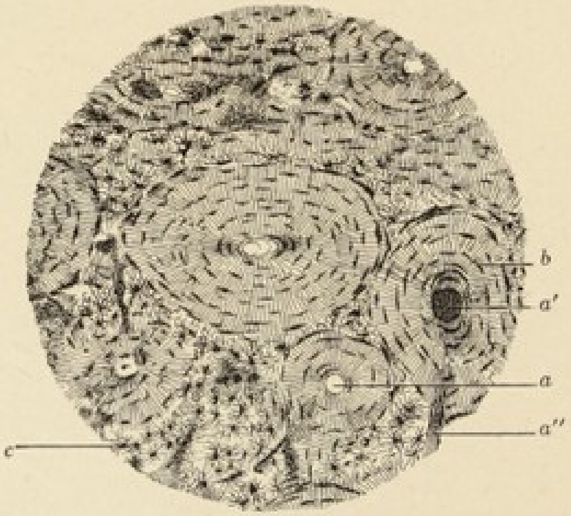
Fig. 23.—Simple saccular gland: *f*, duct; *g*, acinus.

FIG. 24



Elastic cartilage. Section from cartilage of human external ear. *a*, cartilage cell; *b*, *c*, network of elastic fibers in the intercellular substance; *b*, with large meshes; *c*, fine meshed. Opposite *a* is a cell showing indications of a division of the cytoplasm following division of the nucleus. (Böhm and Davidoff.)

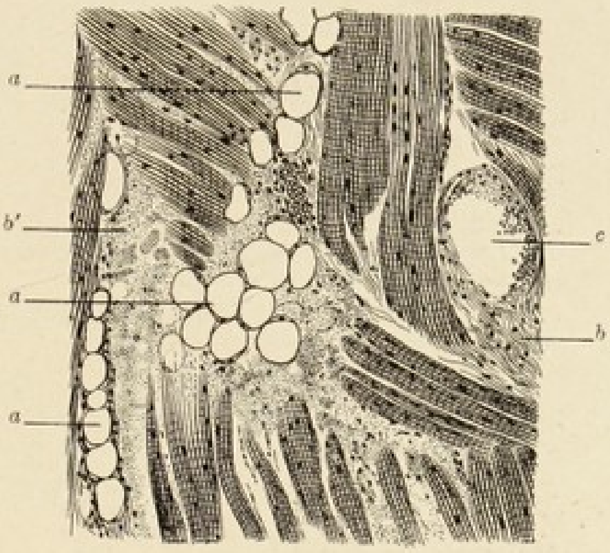
FIG. 25



Ground section of dried bone. Human femur. *a*, Haversian canal in cross-section; *a'*, Haversian canal occupied by débris; *a''*, anastomosing branch from *a'*, in nearly longitudinal section; *b*, lacuna belonging to the Haversian system, of which *a'* occupies the centre; *c*, lacuna in excentric laminæ of bone between the Haversian systems. The delicate lines connecting the lacunæ are the canaliculi. (Dunham.)

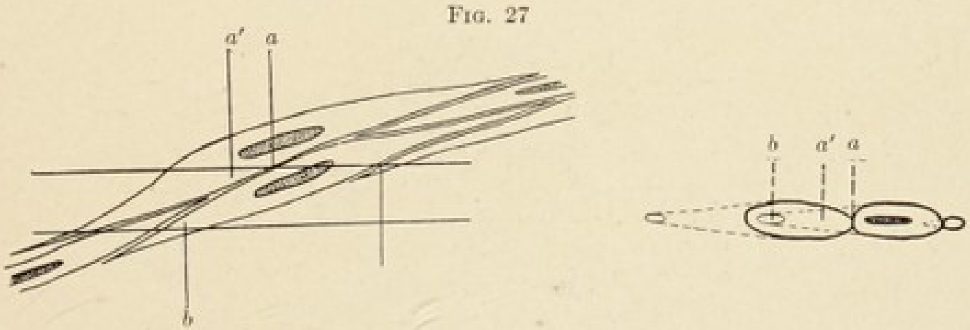
and gain their importance chiefly through the intercellular substances. One of their primary functions is to fill the spaces between organs. The four following kinds of connective tissue are recognized;

FIG. 26



Section from the tongue of a rabbit. *a, a, a,* groups of fat cells forming small massese of adipose tissue in the connective tissue; *b, b'*, fibrous tissue, *b* in longitudinal, and *b'* in cross-section; *c*, small vein containing a few red blood corpuscles. Near the centre of the figure is another blood-vessel filled with corpuscles. The remainder of the figure represents striated muscle fibers in nearly longitudinal section. In the upper left-hand corner these show a tendency to split into longitudinal fibers (sarcostyles). (Dunham.)

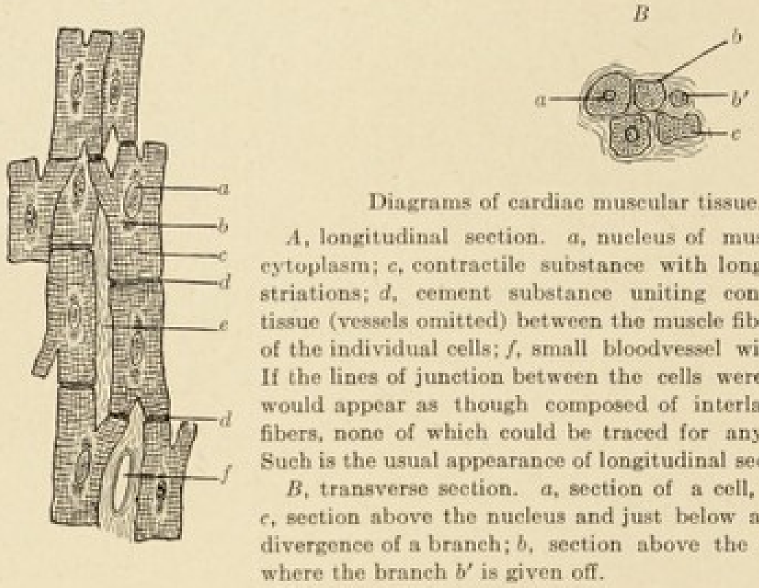
FIG. 27



Diagrams of smooth muscular fibers cut very obliquely. In this case the outlines of the fibers in section will be less sharply defined than in the preceding case, because, for instance, at the point *a* the fiber *a'* is cut so as to leave only a thin edge, difficult of detection, and the fiber *b* has had such a thin slice removed from it that the loss would be hardly perceptible. The appearance of the section would, therefore, be much less easy of interpretation than is represented in the lower figure, where the outlines of the sections are equally distinct throughout. (Dunham.)

(*a*) fibrous; (*b*) adipose; (*c*) cartilage; (*d*) bone. By some the blood is regarded as a modified form of connective tissue, the plasma being the intercellular substance and the corpuscles the living part of the tissue; while others regard the blood as simply a nutritive fluid of which there are two kinds, (*a*) the blood proper and (*b*) the lymph.

Fig. 28

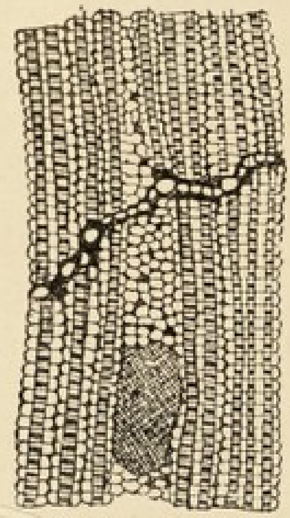


Diagrams of cardiac muscular tissue. (Dunham.)

A, longitudinal section. *a*, nucleus of muscle cell; *b*, unmodified cytoplasm; *c*, contractile substance with longitudinal and transverse striations; *d*, cement substance uniting contiguous cells; *e*, areolar tissue (vessels omitted) between the muscle fibers formed by the union of the individual cells; *f*, small bloodvessel within the areolar tissue. If the lines of junction between the cells were not visible, the tissue would appear as though composed of interlacing and anastomosing fibers, none of which could be traced for any considerable distance. Such is the usual appearance of longitudinal sections of cardiac muscle.

B, transverse section. *a*, section of a cell, including the nucleus; *c*, section above the nucleus and just below a crotch formed by the divergence of a branch; *b*, section above the nucleus and the point where the branch *b'* is given off.

Fig. 29



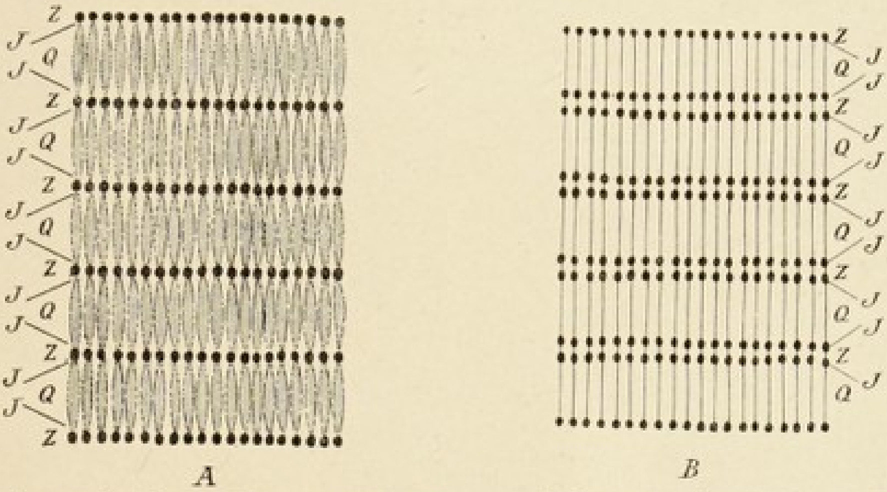
Longitudinal section of heart muscle from an adult dog, showing protoplasmic bridges between two cells. (MacCallum.)

3. *Muscular Tissue.*—Muscular tissues are sharply distinguished from all other tissues by their function. Muscle cells work by shortening and correspondingly increasing their diameter. This property of contraction is an intensification of the fundamental power of movement in protoplasm, the movement here becomes definite. There are two varieties, (*a*) smooth or involuntary, and

(*b*) striated or voluntary. The muscles of the heart form an exception to these two classes.

4. *Nervous Tissues.*—Nervous tissue serves to conduct stimuli and as such must connect the sensory surfaces with the central nervous system, and also the muscles with the coördinating centre. The elements are ganglion cells and their nerve fibers. The ganglion cells are confined to the central nervous system or to small ganglia just outside of this system. The nerve fibers are naked and sheathed.

Fig. 30



Striated muscular tissue. Diagrams of the structure of the contractile substance. *Q*, sarcous elements, appearing dark in *A*, light in *B*; *Z* and *J*, sarcoplasm. The sarcoplasm also lies between the sarcous elements in *Q*, appearing as light bands in *A* and as dark lines in *B*. *A* is the appearance of the fiber when the focal plane is deep; *B*, the appearance when the focal plane is superficial. The dots *Z* in *A* and *J* in *B* are optical expressions of differences in the refraction of the sarcoplasm and sarcous elements, and do not represent actual structures. A complete explanation of the way in which a microscopic image may contain apparent objects which have no actual existence cannot be entered into here. It is due to the fact that regularly alternating structures of different powers of refraction affect rays of light very much as they are affected by a fine grating, producing diffraction spectra. These spectra may interfere with each other, occasioning an alternation of light and dark bands or areas above the specimen. (Rollet.)

The Cell.—All tissues are defined in terms of the cell which is the smallest unit of structure in biology. While the cell is very small, it is perplexingly complex. In the last analysis most of the biological problems are problems of the cell and for this reason a clear understanding of its parts is necessary. The histological study of the intestine as well as Figs. 18 and 24 show that cells vary widely in shape. In some instances the shape is obviously the result of the pressure brought to bear upon the tissue as in columnar cells; while in others there is a widely branching condition which suggests that the shape may be influenced by the nature of the tissue. The spherical ovum is probably the typical shape for a cell and is regarded as the most primitive form of cells. The parts of a cell may be described by taking a typical cell in the non-dividing stage. This stage is frequently referred to as the "resting stage" but a cell is always metabolically active and irregularly reproductively active so that the term resting stage as applied to a cell is misleading. The term cell was coined by Robert Hooke, 1665, while working on the vegetal tissue cork, he reported that it was composed of "little boxes or cells distinct from one another." What he saw was but the outer limiting membrane, all of the living substance being absent in cork.

Fig. 31

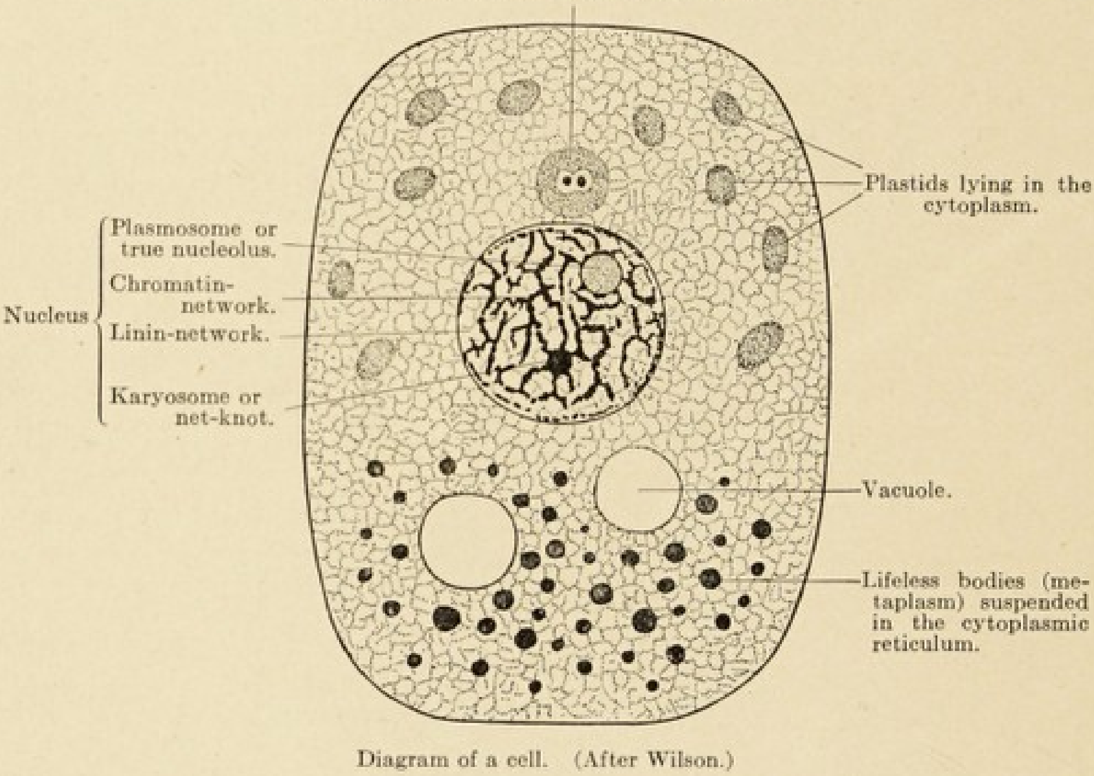


Diagram of a cell. (After Wilson.)

Cell Theory.—In 1838 appeared the memorable contribution of Schleiden and Schwann, who declared as a result of their researches that every plant and animal was composed of cells. Many other investigators verified their conclusions until now their names are always associated with one of the few great generalizations in biology, the cell theory of Schleiden and Schwann. This doctrine implies three propositions: (1) That all organisms can structurally be resolved into cell units, no matter how complex or how simple; (2) that every organism begins life as a single cell which by growth and differentiation gradually assumes the adult form; (3) that the functions or work of all organisms can be interpreted in terms of the activity of its individual cells. "No other biological generalization," says Professor Wilson, "save only the theory of organic evolution has brought so many apparently diverse phenomena under a common point of view, or has accomplished more for the unification of knowledge." The living substance within the cell was named *Protoplasm* by Hugo von Mohl (1846) although the term was earlier used by Purkinje (1840) to designate the formative material of young embryos. Leydig and Max Schultze about 1860 defined a cell as "a mass of protoplasm containing a nucleus."

Protoplasm.—The protoplasm of a cell consists of (1) a *nucleus*, first described by Fontana in 1871, and regarded as a normal element of the cell by Robert Brown in 1883; (2) the *cytoplasm*, a term formulated by Kölliker in 1863, which by usuage has come to be applied to the living substance of the cell-body other than nuclear, although this was not its first meaning; (3) the usual presence of a cell membrane. The nucleus is usually of rounded form and embedded in the cytoplasm. There is a definite nuclear membrane in most instances when the nucleus is not dividing. Within the nucleus there are two classes of bodies: (*a*) A chromatin network; (*b*) achromatic substances. The one or more rounded nucleoli belong to the first class. The cytoplasm presents a variety of appearances largely depending upon the kind of cell being studied and the stains employed. It is to be regarded as a chemical mixture in which the elements assume various forms. The nucleus and cytoplasm constitute a unit of structure. The subject of cells will receive more extended consideration in the section of this book devoted to the Biology of Cells.

CHAPTER VI

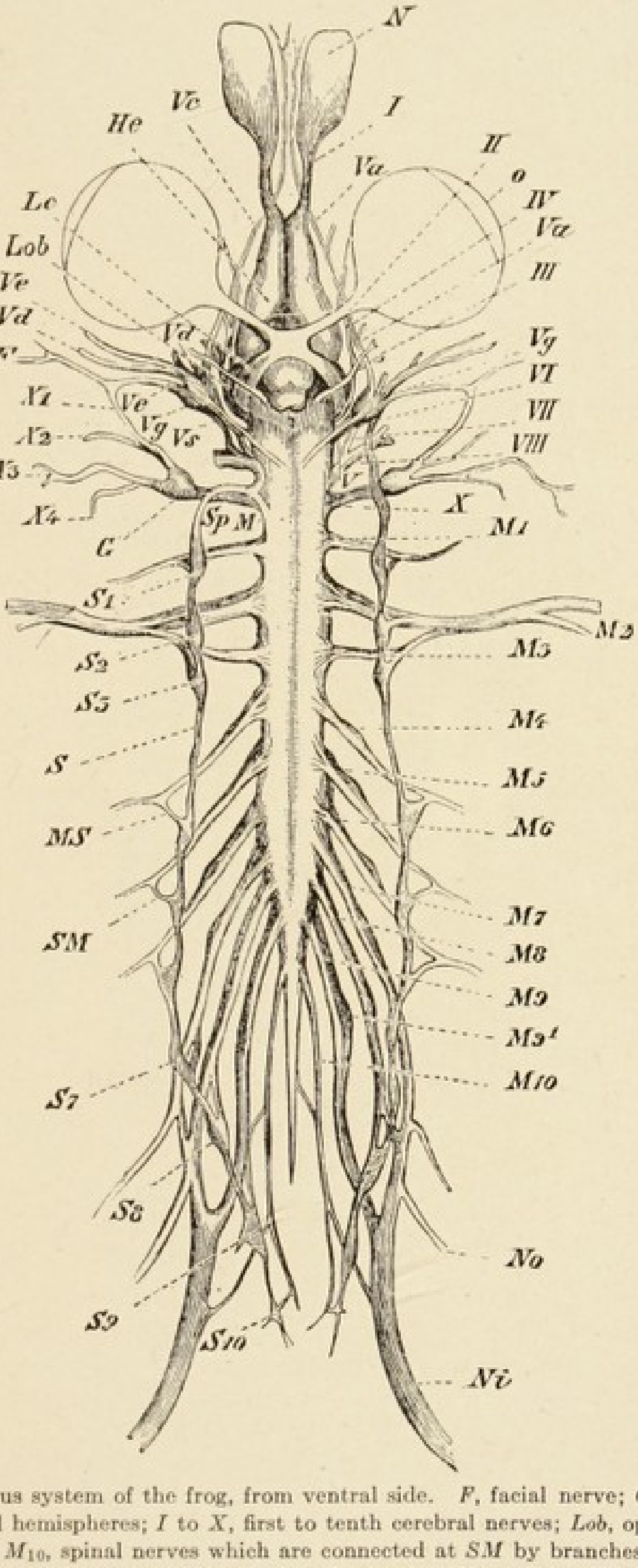
NERVOUS SYSTEM OF THE FROG

LABORATORY STUDY.—Dissection of the central nervous system, peripheral and sympathetic nerves. Demonstration by instructor of reflex action and centres that regulate swimming, automatic action, orientation, etc., by operations on given regions of the brain of an anesthetized frog. Microscopic study of cross-section of spinal cord.

Tissues of Central Nervous System.—The nervous system is composed of three distinct tissues, two of which play a minor although essential part in the work of the whole system. These minor tissues are the connective and blood; the former supply the protective sheaths and supporting framework, while the latter carry food to all parts and remove the wastes of metabolism. While these two tissues are everywhere present yet they occupy but a relatively small part of the nervous system. The third tissue is the nervous which represents the most highly specialized cells found in any tissue. Pure nerve tissue such as exists for epithelium, is not found in the frog, for the nerve cells rarely join and always have in the frog protective and connective cells that bind them together. Again, a pure nerve tissue would be of no service to the frog unless the nerves were connected with the skin, muscles, etc.

Stimuli of Nerves.—The most conspicuous feature of the nervous system is its power of responding to light, heat, touch, sound, etc., that is, to a stimulus. This power of being aware of the various stimuli is based upon a fundamental characteristic of protoplasm, known in biology by the name of irritability. Originally all of the cells possessed this property but as they grew into bone, muscle, etc., there was no need for irritability and it remained undeveloped. But irritability is only part of the work of responding to a stimulus, the light or heat stimulus is conducted along the nerves to the central nervous system. Here it is interpreted and the frog acts according to the nature of the stimulus. For the frog to respond to a stimulus involves the use of three highly developed fundamental protoplasmic properties, *i. e.*, irritability, conductivity, and coördination. These

Fig. 32

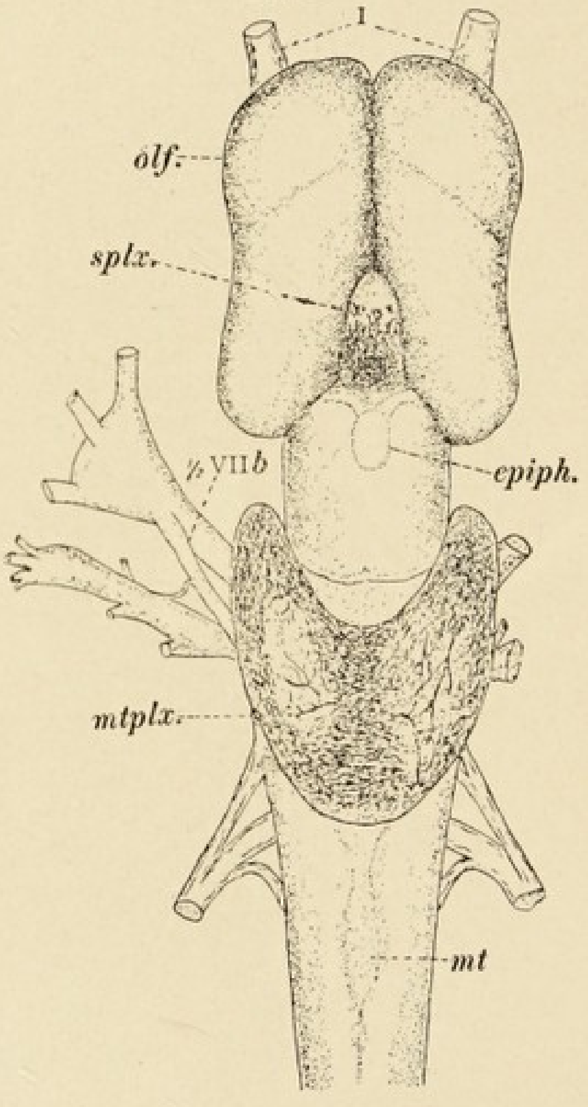


The entire nervous system of the frog, from ventral side. *F*, facial nerve; *G*, ganglion of the vagus; *He*, cerebral hemispheres; *I* to *X*, first to tenth cerebral nerves; *Lob*, optic nerves; *SpM*, spinal cord; M_1 to M_{10}, spinal nerves which are connected at *SM* by branches (*Rami communicans*) with the ganglia (S_1 to S_{10}) of the sympathetic (*S*); *N*, nasal sac; *Ni*, sciatic nerve; *No*, femoral nerve; *o*, eye; *Va* to *Ve*, the different branches of the trigeminal; *Vg*, Gasserian ganglion; *Vs*, connection of the sympathetic with the Gasserian ganglion; X_1 to X_4, the different branches of the vagus. (After A. Ecker, from Wiederschem.)

three processes, then, are at work in every nervous response of the frog.

Central Nervous System.—In order that this controlling system may do its best work, it has been gathered into one structure extending along the main axis of the frog. The central nervous system is the

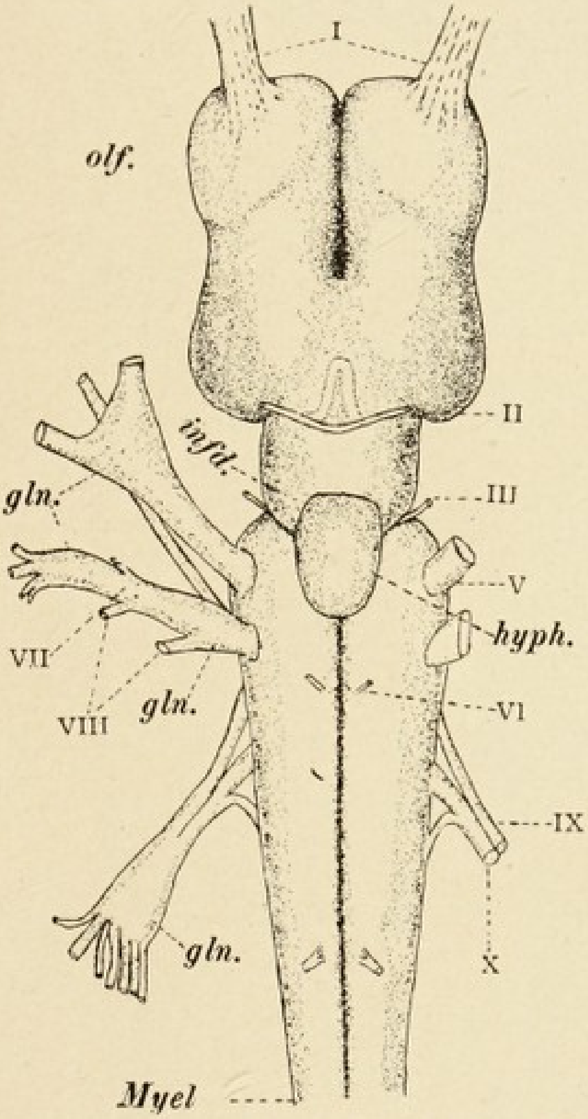
Fig. 33



The brain of *Necturus maculatus*, dorsal aspect. × 5.4. *olf*, olfactory portion of cerebral hemisphere; *splx*, supraplexus; *epiph*, epiphysis; *mtplx*, metaplexus; *mt*, metatela. (Kingsbury.)

name given to this concentration of nervous tissue and it consists of a brain and spinal cord. It is noticeable that there is a marked tendency toward the formation of definite regions in the brain portion and toward giving to each a definite work. This is proved by the fact that the eyes, ears, taste, etc., are all connected with definite regions; for if the brain is removed, the frog loses the power of automaticity. That the brain has not reached a high stage of development is easily seen by an examination of Figs. 32 and 33.

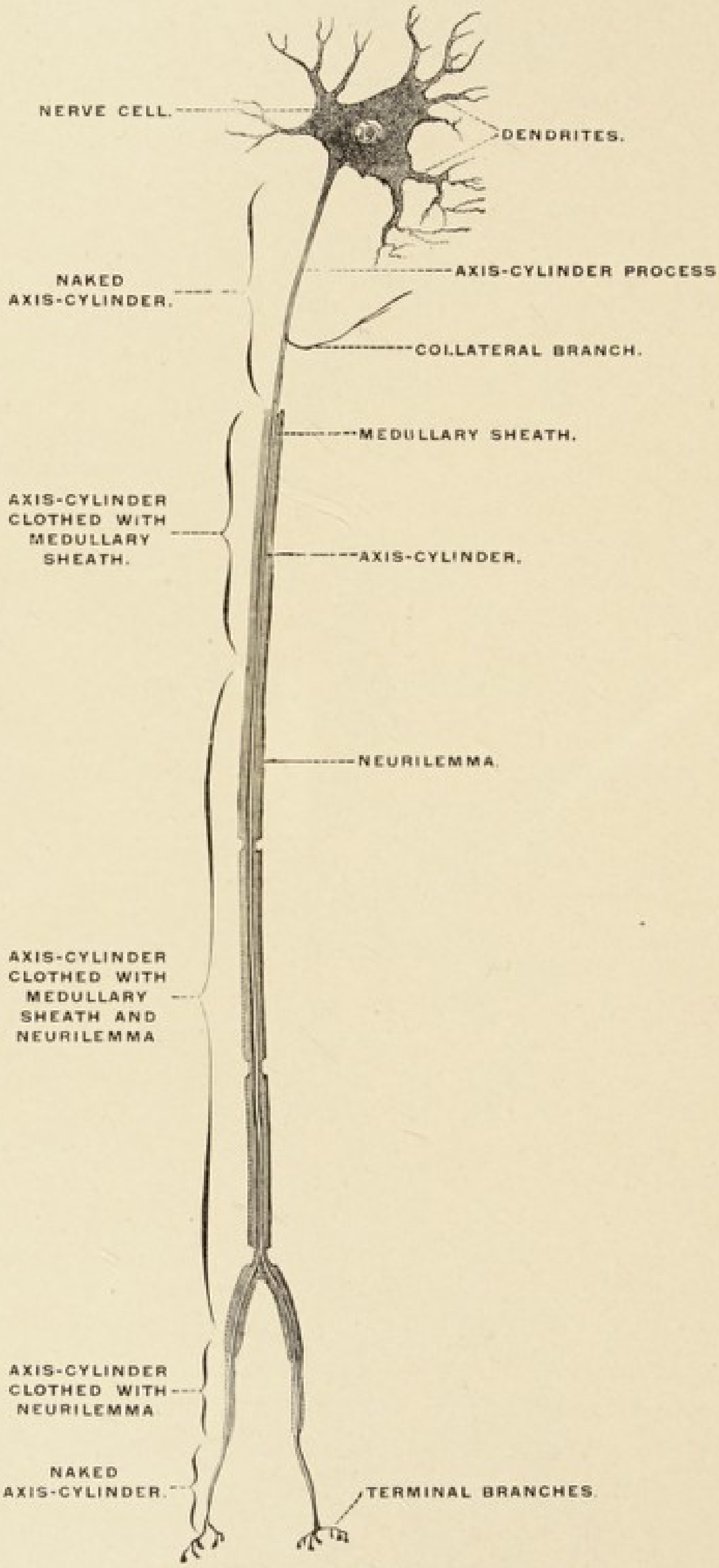
Fig. 34



Brain of *Necturus maculatus*, ventral aspect. × 5.4. Epiphysis; *gln*, ganglion; *hyph*, hypophysis; *infd*, infundibulum; metaplexus; *Myel*, spinal cord; *olf*, olfactory portion of cerebral hemisphere; supraplexus, *I* to *X*, cranial nerves. (Kingsbury.)

Histology of Spinal Cord.—An analysis of the finer structure of the central nervous system will serve to show something of how it works as well as the nature of the nerves. This can easily be done by an examination of a typical cross section of the spinal cord. The whole structure is enclosed in a strong protective membrane, the pia mater. Within the pia mater, the cord is deeply constricted on the dorsal

Fig. 35



Schema of a neuron. (After Verworn.)

and ventral surfaces. These constrictions are the dorsal and ventral sulcus (posterior and anterior fissures of human anatomy). The area of the cord is made up of a peripheral layer of white substance and a central area of gray substance. In the region of the origin of the spinal nerves, the gray substance may extend through the white to the surface of the cord. This gives to the gray substance much the shape of an expanded butterfly.

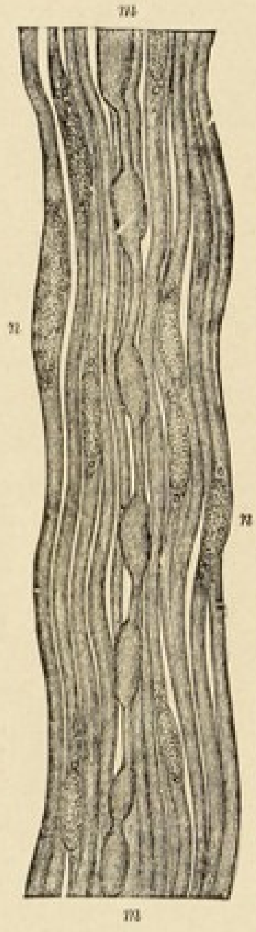
Neuron.—Before explaining the distinction between the white and gray areas, the nerve cell must be studied.

Neuron	Cell body	Cytoplasm
		Nucleus
	Processes	Dendrites
		Neurite or axon.

This diagram will help to make clear the several parts in this cell which has become so highly specialized. The term neuron is given to the nerve cell which is to be regarded as a unit of structure. The cell body is much like other cells varying in shape and size but when the processes are considered, the great distinction of the nerve cell is recognized. The large cells in the ventral region of the gray substance as seen in the laboratory had several short processes that branched, these are the dendritic processes. Each of these cells was somewhat conical and from the point a slender non-branching process arose which could be traced but a short distance, this is the neurite or axon. By the use of special nerve stains, the axon of these cells could be traced out into the nerve roots that rise from the ventral region of the cord. This axon continued in the nerve to finally end in some muscle. Thus the axons that pass to the hind feet might be six inches long which would make the total bulk of the axon many times that of the cell body which produced it.

Origin of Axon.—The nerve cells arise in the embryo as rather regular columnar epithelial cells with an entire absence of processes. As the embryo frog develops, small outgrowths arise on the cells that are to become neurons. These continue to grow deriving their growing energy from the cell body. As they first arise, they are naked processes many of which remain as such throughout the life of the frog; but part of them become surrounded by well defined, thick, fatty sheaths which are secreted by the axon which is thus enveloped. In the cross section of the spinal cord naked and sheathed fibers or axons can be distinguished. It is now easy to understand the difference between the white and gray substance; the white consists of sheathed fibers extending lengthwise of the cord, while the gray is made up of many cell bodies and unsheathed fibers.

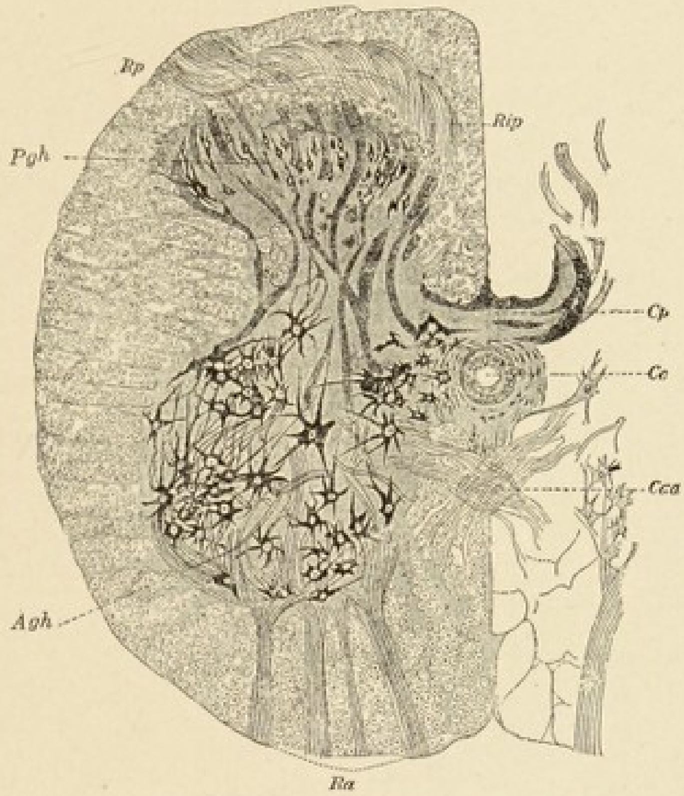
Fig. 36



Nerve fibers from the sympathetic system. All the fibers except that marked *m* are non-medullated. The fiber *m* has an incomplete medullary sheath. *n*, *n*, nuclei of the neurilemma. These are surrounded by a small amount of cytoplasm, which is not clearly represented in this figure. (Key and Retzius.)

Nerves.—In every segment of the spinal cord, a pair of spinal nerves passes off from the cord. Each nerve arises by two roots from the cord; one from the dorsal region, and one from the ventral. On the dorsal root, there is a small enlargement that contains many cell bodies which give origin to nerve processes. The presence of these nerve cells on the dorsal root distinguishes the two roots as to form as well as to function. The ventral root is mostly made up of fibers which grow out from the large cells in the ventral region of the gray substance and the most of them end in some muscle. This means that the nerve stimulus travels outward and away from the spinal cord over these fibers. This also means that these fibers cannot be stimulated normally except through the spinal cord. The term motor or efferent is given to the ventral root. The dorsal root consists exclusively of fibers which arise from the cells in the dorsal ganglion. Part of these fibers pass out into a nerve and are

Fig. 37



Half of a section through the lumbar cord. *Ra*, anterior root; *Rp*, posterior root; *Rip*, inner portion of the posterior root; *Cp*, posterior commissure; *Caa*, anterior commissure; *Cc*, central canal. The fine network of medullary fibers in the gray matter and the network of medullary fasciculi in the otherwise gray posterior commissure are not shown. *Agh*, anterior gray horn; *Pgh*, posterior gray horn. (Edinger, after Deiters.)

enclosed in the same general sheath with those from the ventral root for a part of the way. The dorsal root fibers end in the skin. From the same dorsal ganglion cells fibers grow into the spinal cord and send branches in several well known directions. The normal stimulus for the dorsal root fibers is something that reacts on the fiber ending in the skin. This stimulus is carried to the spinal cord where it is interpreted usually through the assistance of the brain; and the resulting explanation is sent out over the motor fibers to the muscles. The dorsal root, then, is known as the sensory or afferent root. Such is the structural plan of each spinal nerve. The nerves that arise from the brain have lost some of their primitive parts and each must be studied separately. Within the central nervous system there are many definite paths over which certain nerve impulses travel but their study belongs to a course in neurology.

Movement Analyzed.—The power to make a definite kind of movement was characterized in the first chapter as an exclusive property of living things. The kind of movement meant was such as grows out of the complex series of interacting stimuli just described. The frog may be assumed to see a man approaching, the sight stimulus is carried to the brain and there is sent out a series of stimuli to the muscles which results in a series of movements so directed that the frog is able to jump into the water and swim away from shore. It makes very little difference how this fundamental characteristic of living matter is named; it may be called movement, coördination or response to a stimulus (having the property of irritability). The fact remains that it is universal in all of the simpler organisms as well as in all higher animals. The tendency for the higher plants to remain stationary has resulted in the elimination of this property. Movement in its simplest expression is regarded as regulated by the nervous system without the intervention of the brain. The stimulus comes from the skin and is reflected by the cord on to the muscles; and so the term reflex action is employed to describe the simple forms of movement.

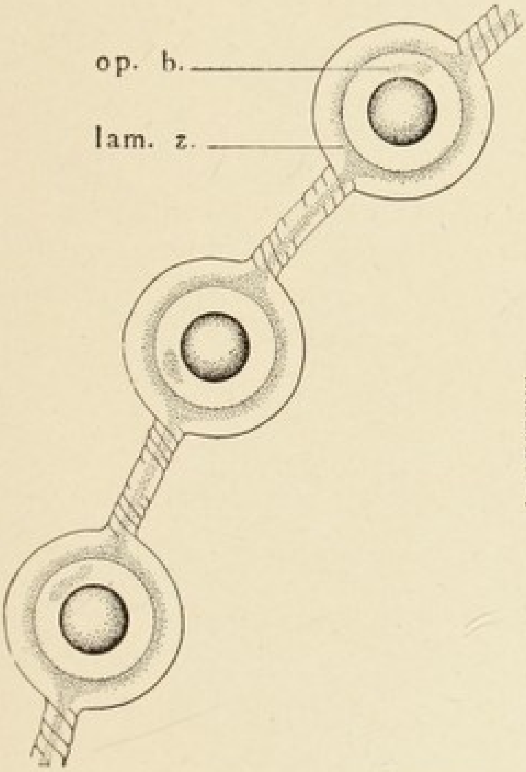
CHAPTER VII

EMBRYOLOGY

Laboratory Study.—Study the early cleavage of the frog's egg and the external features of advanced stages, also living tadpoles of various ages. This section may well be postponed until living material is at hand in the spring.

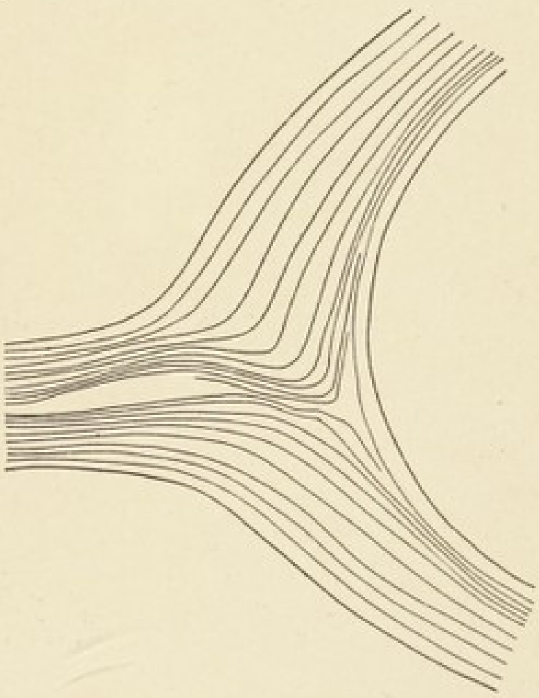
Somatic and Germ Cells.—Until one has actually seen the single celled ovum change into many cells, elongate, and become a tadpole

Fig. 38



Eggs and egg envelopes of *Cryptobranchus*, natural size. *op. b*, opaque body; *lam. z*, lamellar zone of the envelope. (B. G. Smith, in *Journal of Morphology*.)

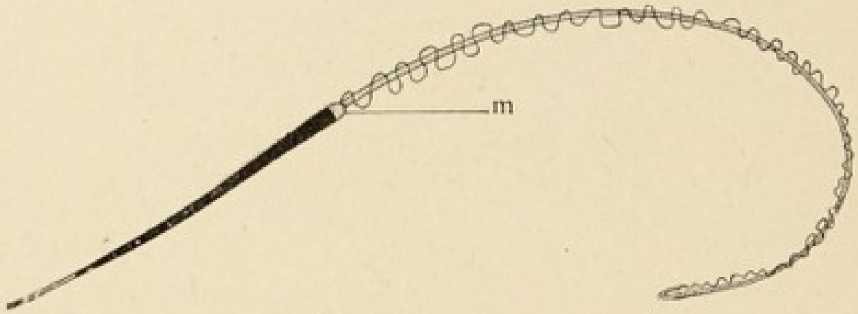
Fig. 39



Optical longitudinal section through the lamellar zone of the envelope in the region of the junction of the egg capsule with the connecting cord. × 13. (B. G. Smith, in *Journal of Morphology*.)

and finally a frog, the statement that such is the sequence of events seems incredible. In selecting the frog to illustrate the principle of growth and the origin of a new organism in Nature, for the two are continuous and inseparable processes, the purpose is to consider it in its broader aspects. The parent frogs possess either spermaries

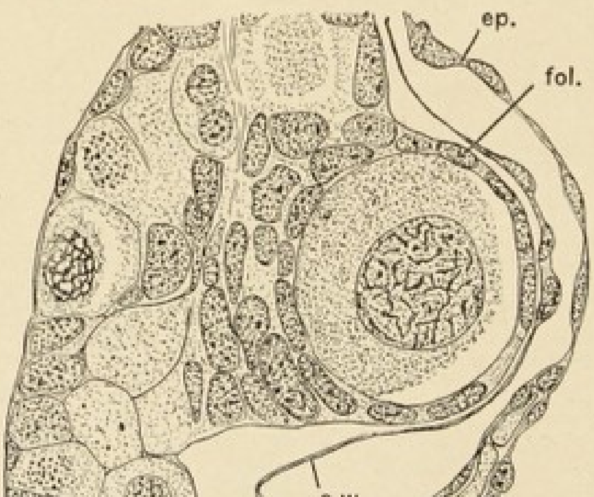
Fig. 40



Spermatozoön. *m*, middle piece. × 500. (B. G. Smith, in *Journal of Morphology*.)

in which are produced sperms or ovaries that grow many ova. Both sperms and ova are free cells and do not unite to form tissues like epithelium or muscle. This free state is a primitive condition and if these cells had some physiological work like digestion to perform, they would be inefficient. But early in the life of the frog, the cells

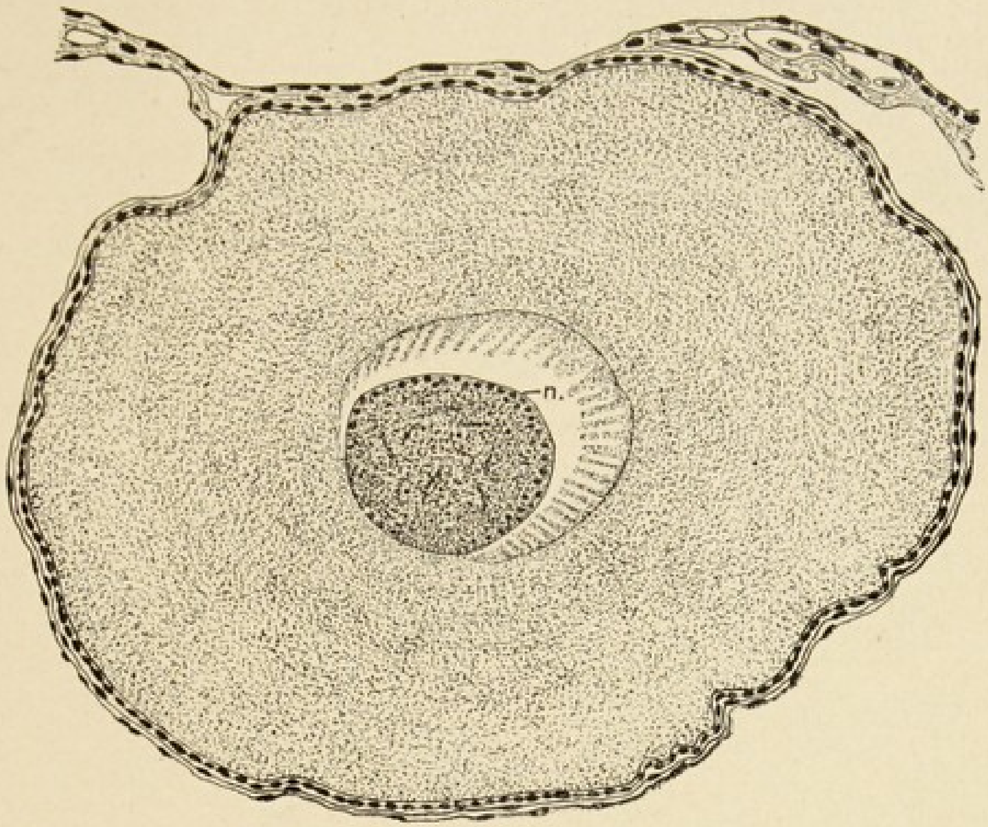
Fig. 41



Young ovocyte of *Cryptobranchus*. *ep*, inner epithelial membrane of the ovarian wall; *fol*, follicle cell; *c.w*, cyst wall. (B. G. Smith, in *Journal of Morphology*.)

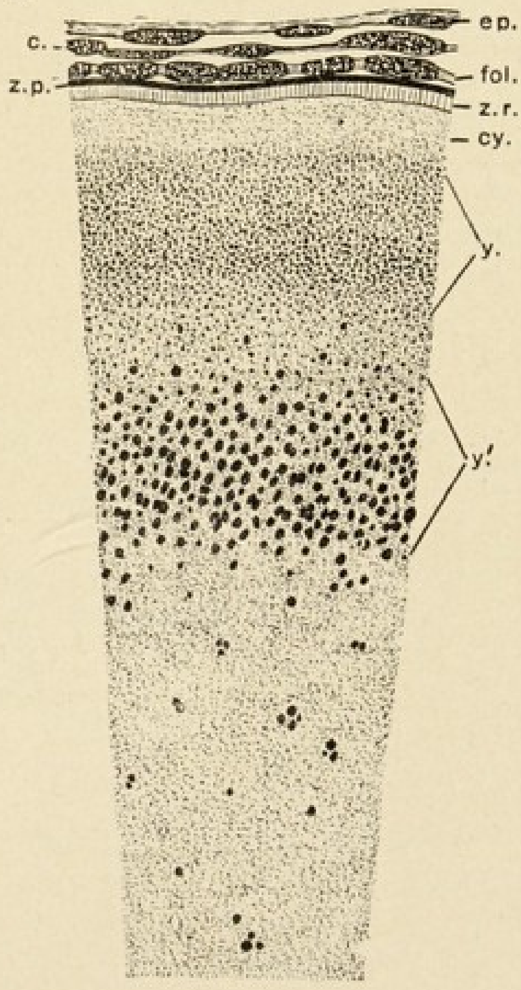
which are to be responsible for growing sperms and ova are set apart and do not continue to develop into the highly specialized adult tissue cells. This gives in each frog one set of cells that continue

FIG. 42



Section through an ovocyte and ovarian wall of 35 cm. *Cryptobranchus*, showing the follicle and the distribution of nucleoli. (B. G. Smith, in *Journal of Morphology*.)

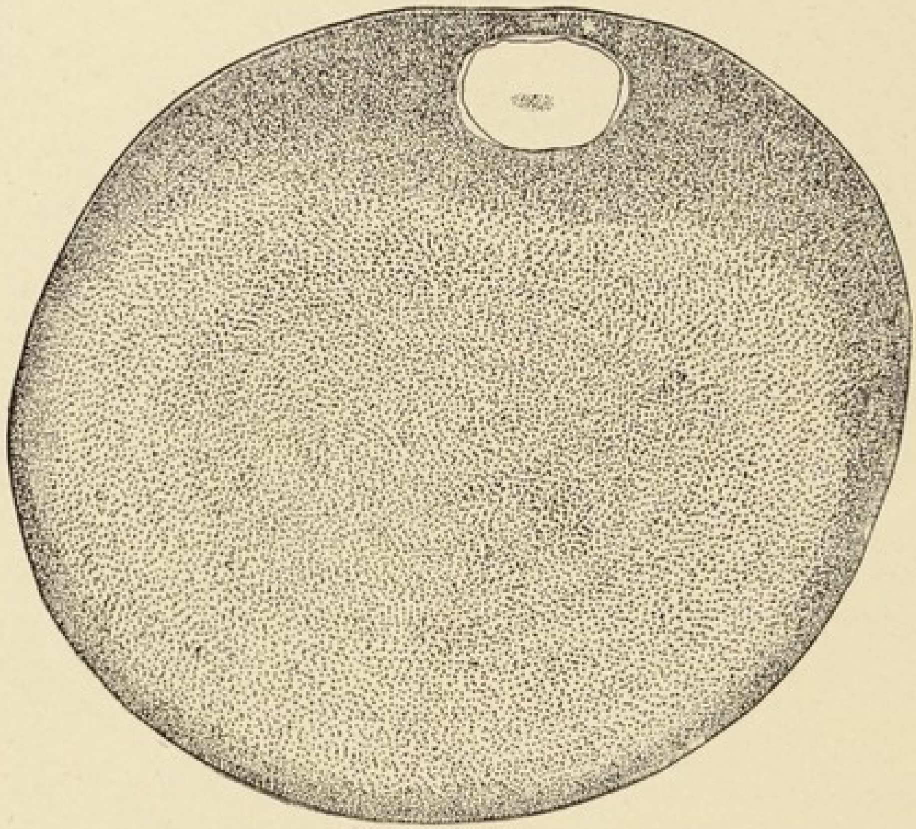
FIG. 43



Portion of a section through one of the most advanced ovocytes of a 35 cm. *Cryptobranchus*, showing the structure of the membranes surrounding the egg and the early formation and distribution of yolk granules. ×340. *c*, cyst membrane; *cy*, yolk-free peripheral zone of cytoplasm; *ep*, inner epithelial membrane of the ovarian wall; *fol*, follicular membrane proper; *z.p*, zona pellucida; *z.r*, zona radiata; *y* and *y'*, layers of fine and coarse granules respectively. (B. G. Smith, in *Journal of Morphology*.)

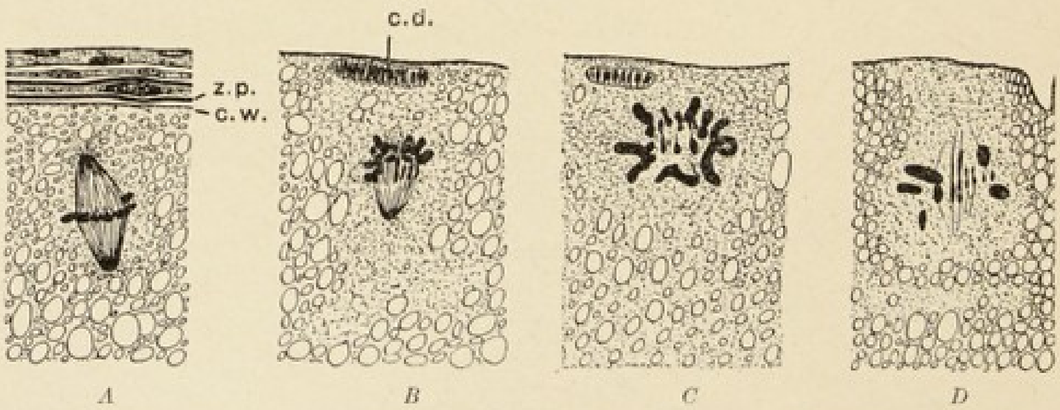
to grow and become highly differentiated eventually taking their place in some complex organ. After they have become thus specialized, they loose their power to grow new cells other than those like the

FIG. 44



Ovarian egg of adult *Cryptobranchus*. (B. G. Smith, in *Journal of Morphology*.)

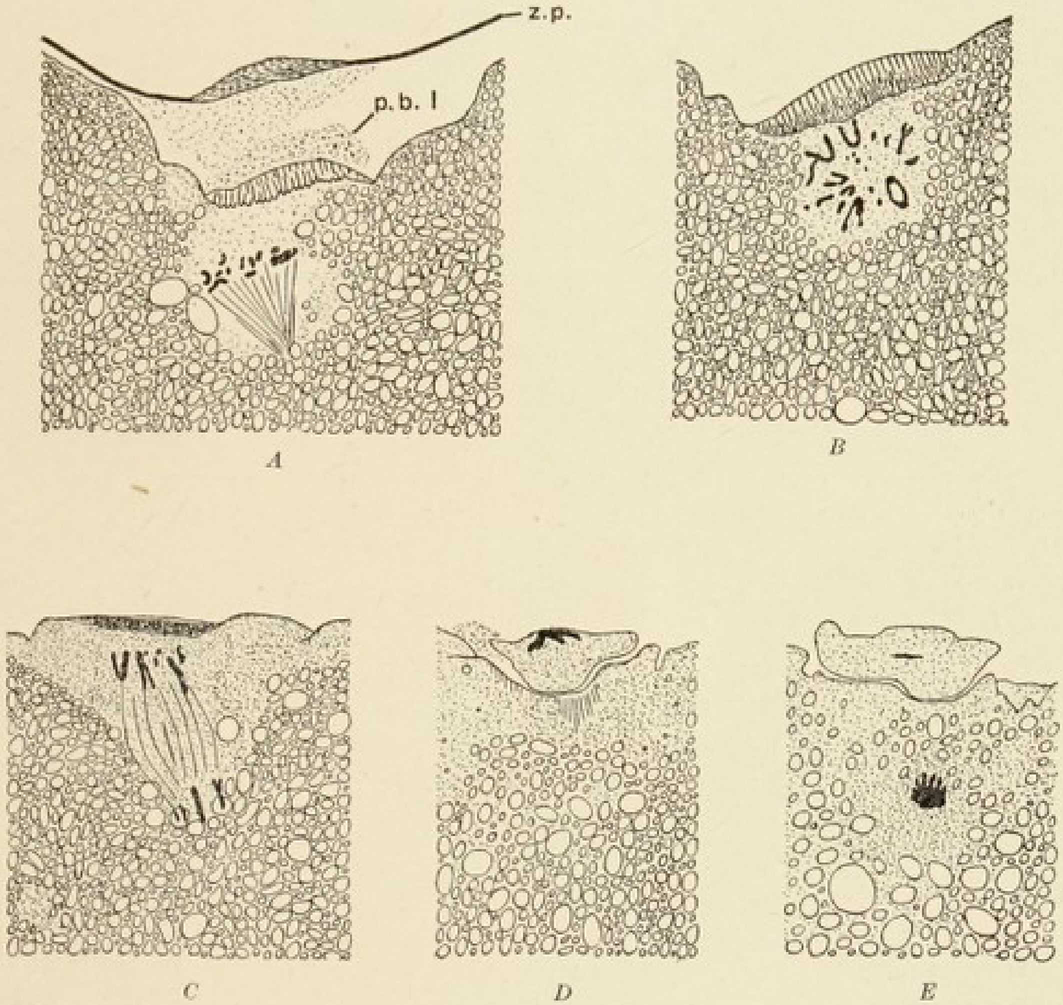
FIG. 45



Showing first polar spindle of *Cryptobranchus*. *c.d*, contact disk; *c.w*, cell wall formed from the zona radiata; *z.p*, zona pellucida. In *C* the section cuts the spindle obliquely and includes all the chromatin except one small chromosome belonging to the central part of the group, which is left in an adjacent section. There are probably six large chromosomes forming a ring surrounding six small chromosomes in a state of division. (B. G. Smith, in *Journal of Morphology*.)

tissue in which they occur. The term somatic cells is given to all such cells. The sperms and ova retain their power to grow new cells and are called germ cells.

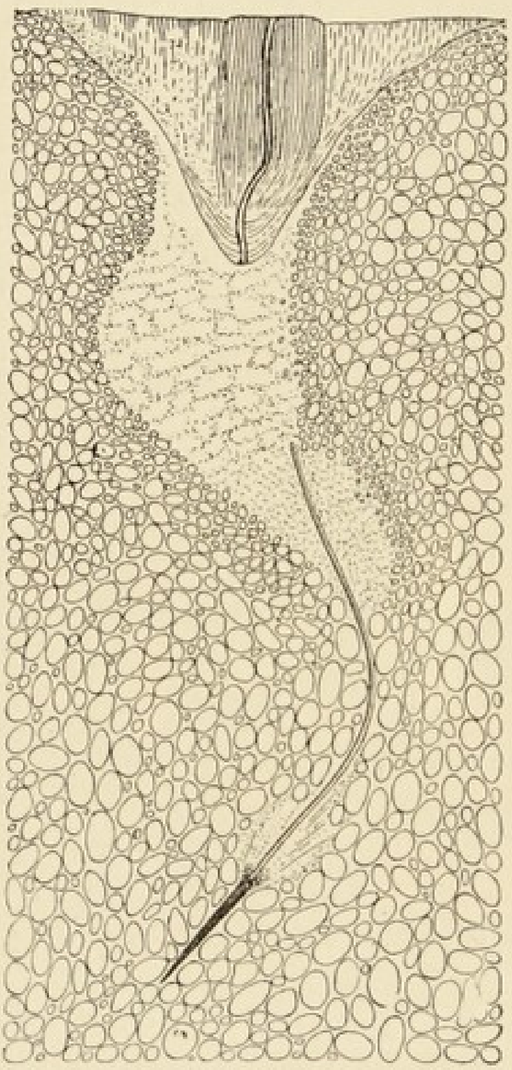
Fig. 46



Sections showing the second polar spindle, and the formation of the second polar body and egg nucleus in *Cryptobranchus*. *z.p*, zona pellucida; *p.b.l*, debris of the degenerating first polar body; *C*, late anaphase second polar spindle; *D*, shows second polar body; *E*, has the newly formed egg nucleus. (B. G. Smith, in *Journal of Morphology*.)

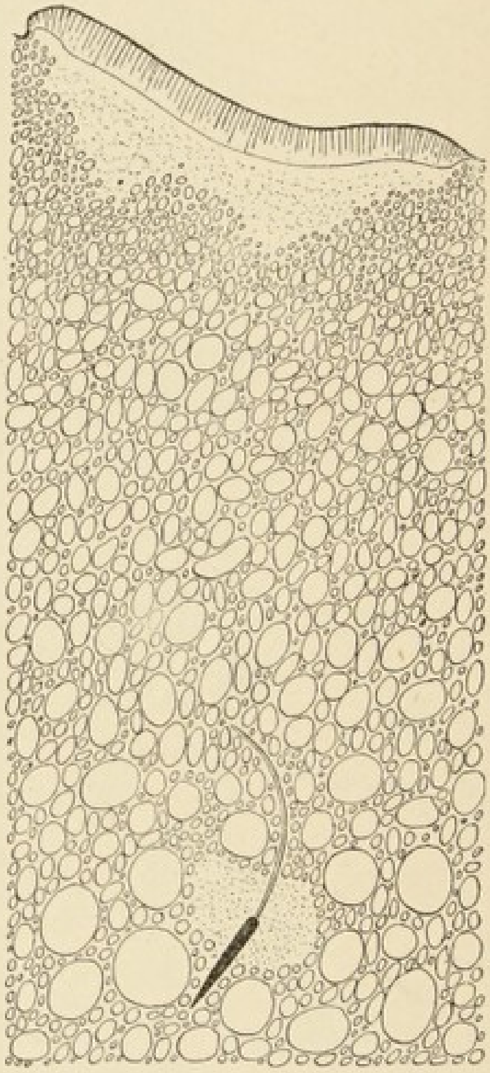
Ova and Sperm Cells.—The ovum of the frog represents a typical cell that has become specialized by the addition of a large amount of stored up food, known as deutoplasm. The result is that most of the cytoplasm and the nucleus are crowded into one region of the ovum. Associated with this concentration of cytoplasm is a black pigment. This pigmented region is called the animal pole of the ovum, and the opposite region, the vegetal pole. The pigmented area is always uppermost and toward the sun because the animal pole is of less specific gravity than the vegetal region. The sperm cell has departed from the rounded primitive shape for cells and assumed a highly specialized form. The cytoplasm has become reduced to

Fig. 47



Vertical sections of eggs of *Cryptobranchus* showing penetration of the egg by a spermatozoön. × 240. Two and one-half hours after fertilization. (B. G. Smith, in *Journal of Morphology*.)

Fig. 48



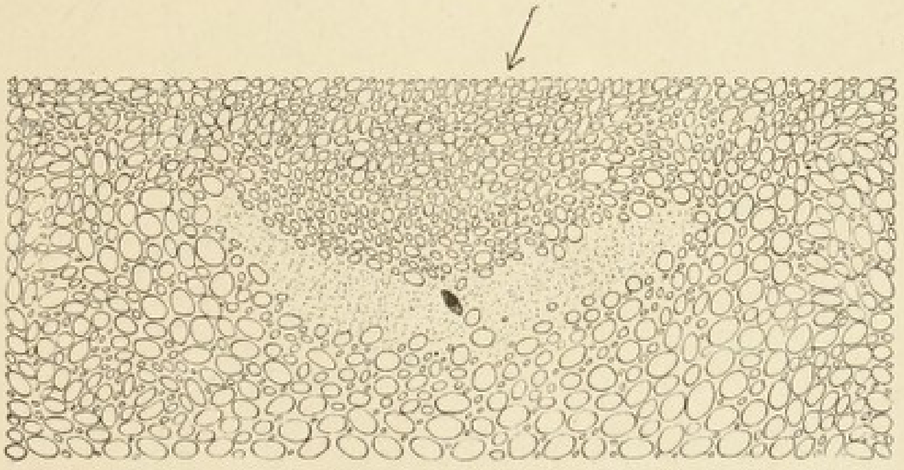
Same as Fig. 47, three hours after fertilization. (B. G. Smith, in *Journal of Morphology*.)

a very small amount and the nucleus is concentrated into a solid mass of chromatin. The long vibratile tail assists in the movement necessary to bring the sperm cell to the ovum.

As the ova are laid the fertilizing fluid is discharged over them by the male and fertilization is effected. The ova are surrounded by a gelatinous substance, secreted by the oviduct, which swells on contact with the water. As this jelly-like substance absorbs water, it increases in thickness. It function is primarily protection. The ova are numerous, spherical bodies about 1.75 mm. in diameter. Black in color, they readily absorb the heat. The sperms and ova may be frozen without being destroyed, if the exposure is short.

Maturation.—The eggs of the frog must undergo important changes before fertilization can be effected. The nucleus of the ovum contains too much chromatin and the excess must be removed and forced through the cell wall (vitelline membrane). The process of getting rid of the chromatin consists in a series of detailed changes that are well illustrated in Figs. 39 and 40. In this process there are two general features that may be emphasized: (1) The changes in the chromatin, (2) the method by which the chromatin is removed. The two processes are so interrelated that they must be described together.

Fig. 49



Same as Fig. 47, five hours after fertilization. (B. G. Smith, in *Journal of Morphology*.)

The mechanism for the removal of the excess of chromatin, consists in the formation of a temporary structure in the cytoplasm. The exact origin of all of its parts is still a subject of controversy and they are not the same in all animals. The conditions in the frog are about the same as shown in the illustration for cryptobranchus. A spindle arises in the cytoplasm close to the egg nucleus and is made up of fibers which extend from pole to pole of the spindle as well as fibers which radiate around each pole, these latter are known as the astral fibers. The astral fibers terminate in a deeply staining body known as the centrosome. As the spindle grows some of the fibers push their way through the weakening nuclear membrane and come in contact with certain chromatic masses that have become larger during the time that the spindle was forming in the cytoplasm. These particular chromatin masses continue to enlarge and become organized into a definite number of discrete chromatin bodies which may now be termed chromosomes. The number in the common toad is 12, in *Rana tamporaria* 10, and in *Cryptobranchus* 12. The chromosomes are drawn into the spindle until they are

FIG. 50

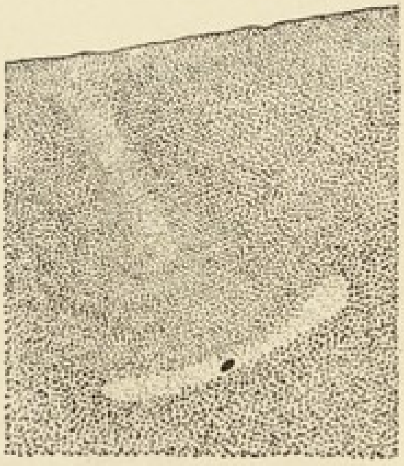


FIG. 51

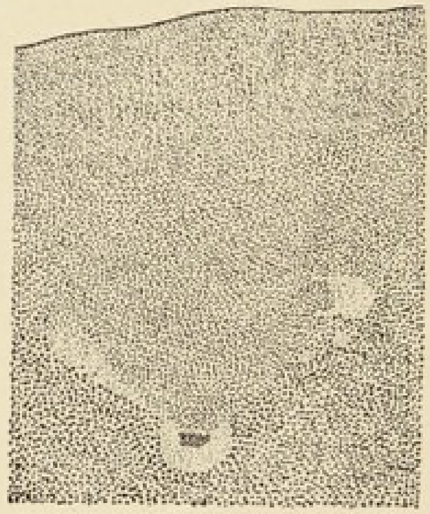


FIG. 52

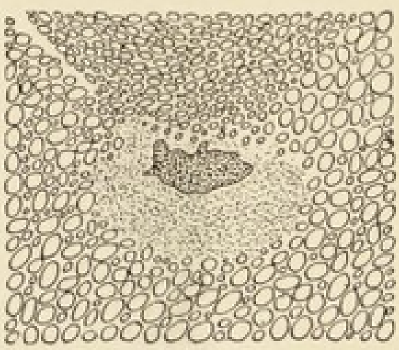


FIG. 53

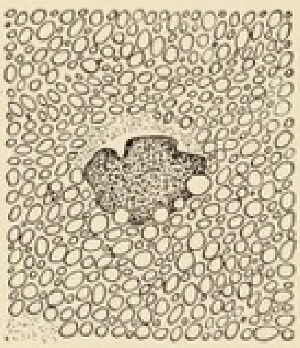
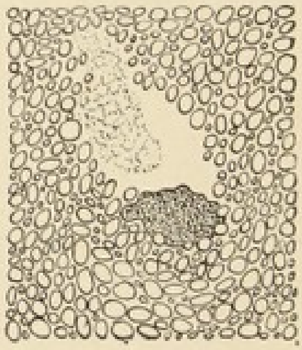


FIG. 54



FIGS. 50 to 54.—Fig. 50, vertical section through an egg killed seven and one-half hours after fertilization, showing a late stage in the penetration of the spermatozoön. Fig. 51, an egg killed ten and one-half hours after fertilization, showing the sperm nucleus. Fig. 52, the sperm nucleus is enlarged three times as much as in Fig. 51. Figs. 53 and 54 are consecutive sections through an egg killed ten and one-half hours after fertilization. (B. G. Smith, in *Journal of Morphology*.)

arranged symmetrically mid-way between the two poles of the spindle. The growth of the spindle and the growth and arranging of the chromosomes between the poles of the spindle is a preparatory process and is named the prophase stage. The complete spindle with the equatorially placed chromosomes is termed the metaphase stage. In a short time the chromosomes are seen to divide and move toward each pole of the spindle. The number of chromosomes and the amount of chromatin is the same in each group. One pole of the spindle is directed toward the periphery of the ovum and by the constriction of a small portion of the cytoplasm, this distal pole of the spindle and the chromosomes associated with it, are cut off from the rest of the ovum. The obvious result is that one-half of the original amount of the chromatin in the nucleus has been removed. The parts removed by this process constitute the first polar cell. The portion of the spindle remaining in the cytoplasm except the centrosome, dissolves in the cytoplasm; and a new spindle arises under the direction of the old centrosome. The work of the new spindle is to repeat the process already described and produce a second polar cell. At the close of the formation of the second polar cell, the remaining chromosomes gradually become transformed into a nucleus but a nucleus that has lost three-fourths of its original amount of chromatin. This process is termed maturation and is preparatory to fertilization. The new nucleus is called the female pronucleus. The two polar cells soon disintergrate and play no further part in development.

FIG. 55

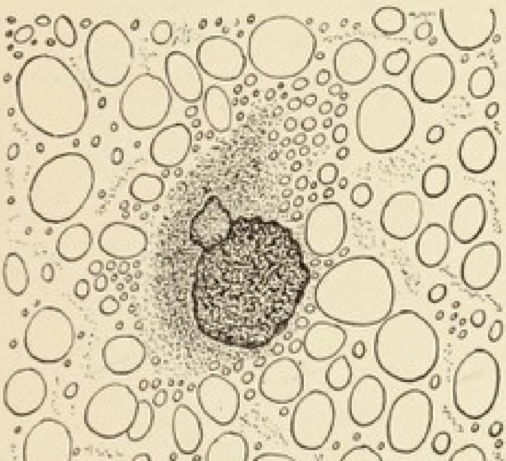
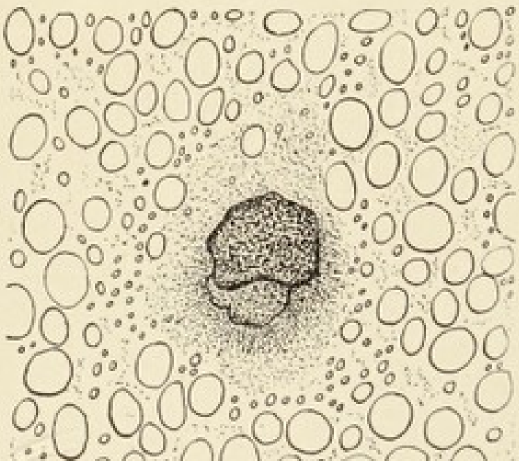


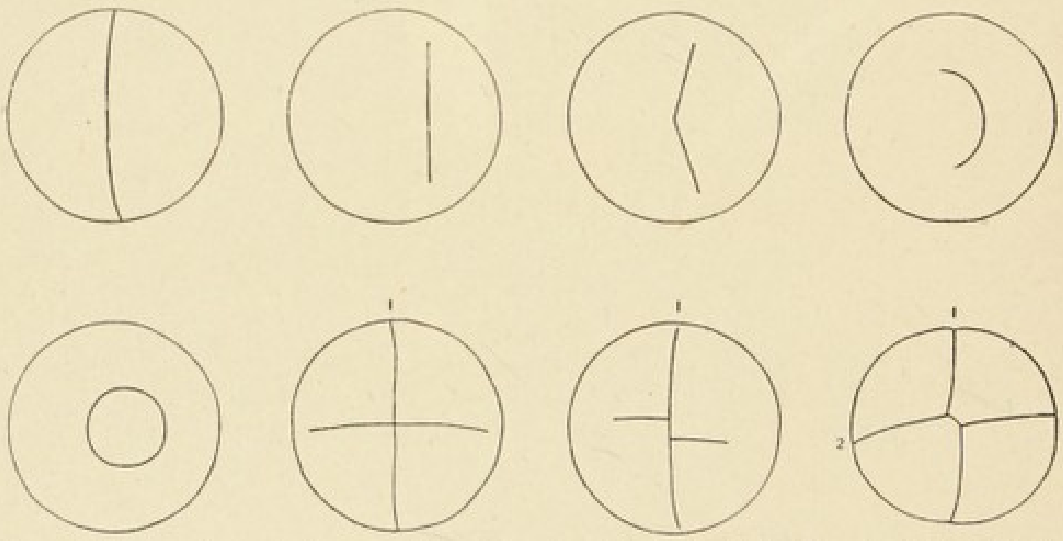
FIG. 56



FIGS. 55 and 56.—Sections through eggs killed twelve hours after fertilization showing the fusion of the male and female pronuclei. The male pronucleus is probably the smaller. (B. G. Smith, in *Journal of Morphology*.)

Fertilization.—While maturation is taking place, the sperm enters the ovum and is gradually transformed into a nucleus. This change results through the growth of the sperm head, which is nearly all chromatin, becoming vacuolated and secreting a nuclear membrane. In appearance this sperm nucleus is like the egg nucleus; while in many instances it is as large, in *Crytobranchus* it is much smaller. As a rule, one must know the exact history of the two nuclei found in an ovum during fertilization in order to be able to tell their origin, so similar are the two. The male nucleus is called the male pronucleus. As the two pronuclei grow to full size, the male pronucleus moves through the cytoplasm until it comes in contact with the female pronucleus. At about this time the nuclear membrane begins to break down and the contents of the two pronuclei become enclosed in a single irregular shaped nucleus. This uniting of the two pronuclei is fertilization. It is difficult to state to just what extent the chromosomes of each pronucleus retain their identity and to what extent they fuse. At any rate the number of chromosomes is not increased by fertilization. This new nucleus is termed the segmentation nucleus and the ovum may now be properly designated as an embryo.

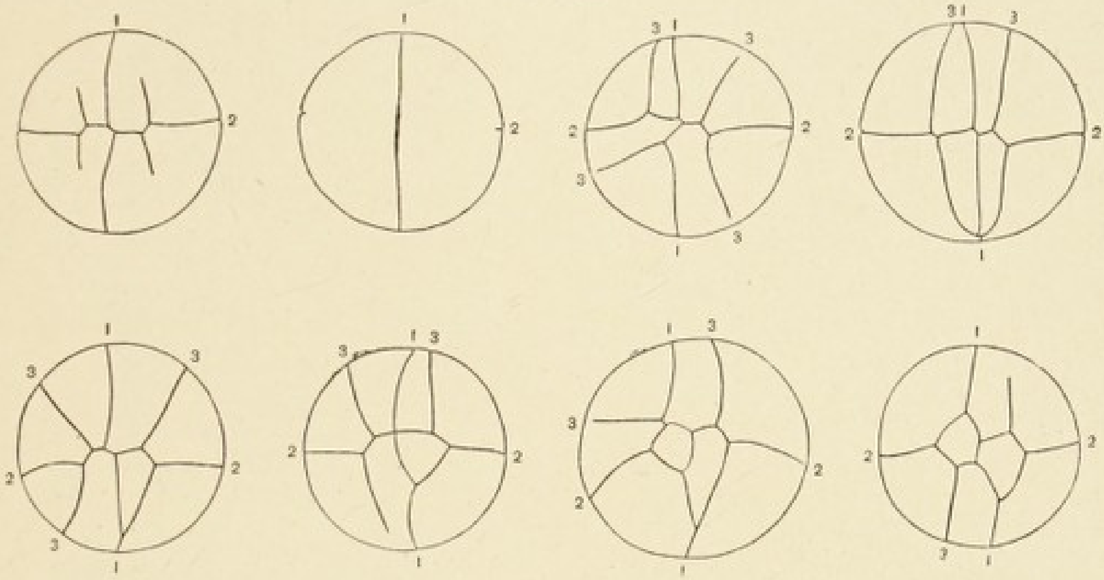
Fig. 57



Types of first and second cleavage of *Cryptobranchus*. (B. G. Smith, in *Journal of Morphology*.)

Segmentation.—After maturation and fertilization the egg begins to show signs of segmentation. The time varies with the temperature, being usually two or three hours after fertilization. Segmentation begins as a furrow on the pigmented region, Figs. 57 and 58. This furrow continues until it surrounds the embryo. A division of the nucleus precedes this cytoplasmic segmentation. The second segmentation begins about three-quarters of an hour after the first and in a similar manner, but in a plane at right angles to the first, Fig. 57. The third segmentation in the frogs is not just like that shown for

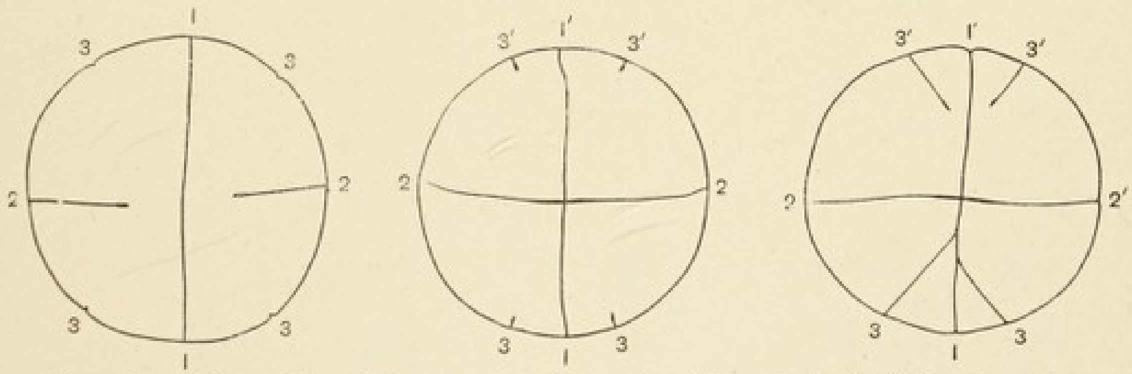
Fig. 58



Types of third cleavage of *Cryptobranchus*. All of the figures are of the upper hemisphere except the second one in the upper row which represents the lower hemisphere of the first egg shown in the upper row. (B. G. Smith, in *Journal of Morphology*.)

Cryptobranchus but is at right angles to the first two and a little above the equator of the embryo, which results in producing eight cells, four small ones at the animal pole and four large ones at the vegetal pole. Segmentation takes place from now on more rapidly at

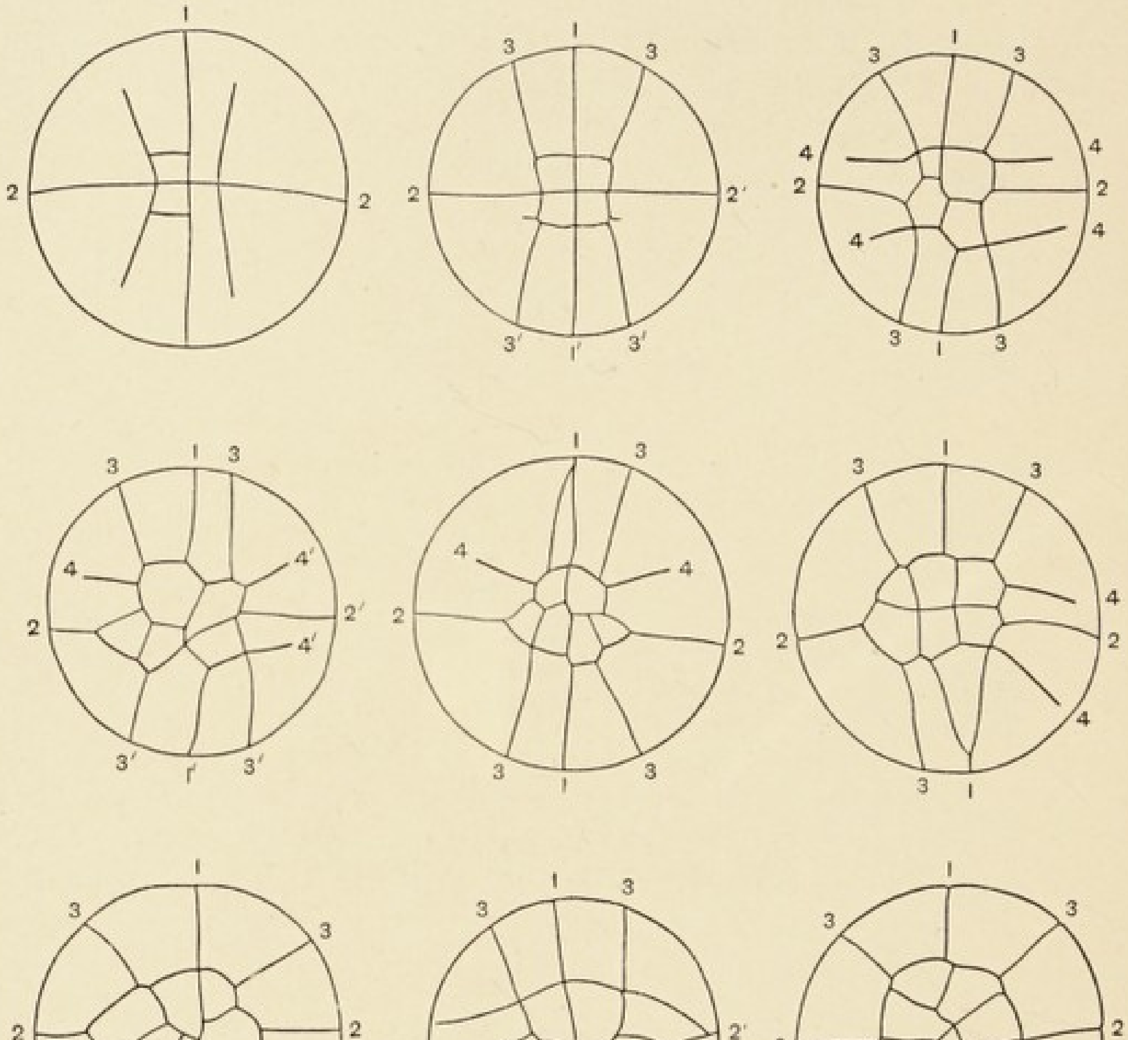
Fig. 59



Lower hemisphere of fourth cleavage stage of *Cryptobranchus*. (B. G. Smith, in *Journal of Morphology*.)

the animal pole and in a short time the cells at the vegetal pole are found to be much larger. The rate of division is intimately associated with the quantity of yolk present. There are a number of external changes which can be readily observed.

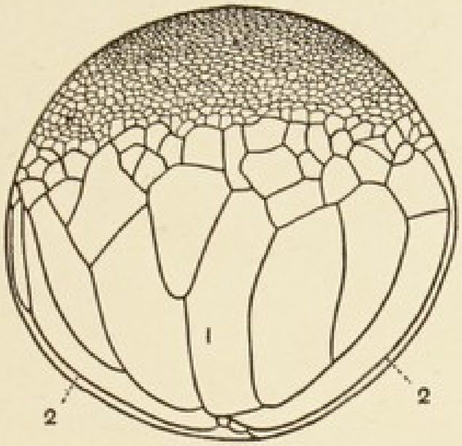
Fig. 60



Upper hemispheres of eggs of *Cryptobranchus*. (B. G. Smith, in *Journal of Morphology*.)

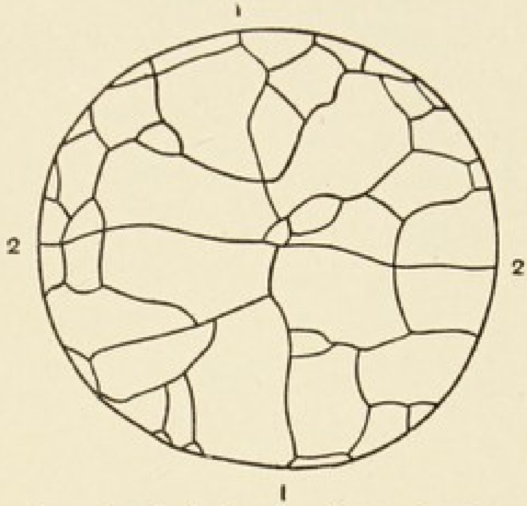
For a considerable time the embryo retains its spherical form and one of the first changes to be noted is a flattening on the dorsal surface. A groove soon appears in this region which is the neural groove. The neural groove closes over, beginning at the anterior end, thus forming the central nervous system. During this time the embryo has elongated in a direction which marks the longitudinal axis of the animal. The mouth, anal opening, nostrils, gill-slits, and sucker appear as the embryo elongates.

Fig. 61



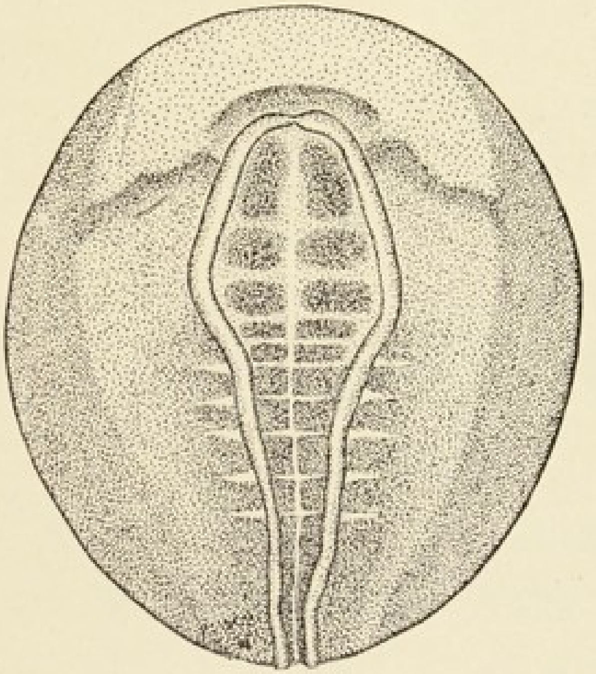
Stage nine of the cleavage of *Cryptobranchus*. Equatorial. (B. G. Smith, in *Journal of Morphology.*)

Fig. 62



Stage nine of the cleavage of *Cryptobranchus*. Lower hemisphere. (B. G. Smith, in *Journal of Morphology.*)

Fig. 63



Anterodorsal view of a living embryo of *Cryptobranchus*, viewed mainly by transmitted light. Free-hand sketch. (B. G. Smith, in *Journal of Morphology.*)

Tadpole.—At the time of hatching the mouth has not become connected with the remainder of the digestive tube and the tadpole is dependent for food on the unused yolk. The tadpole soon attaches itself by means of its sucker to weeds, etc., and breathes by means of external gills. Soon after this stage, the mouth becomes connected with the digestive tube, the intestine increases greatly in length and becomes much coiled and the tadpole feeds on minute animals.

Fig. 64

Diagram of embryo *Cryptobranchus*, showing the direction of the water currents produced by the cilia. (B. G. Smith, in *Journal of Morphology*.)

Fig. 65

Fig. 66

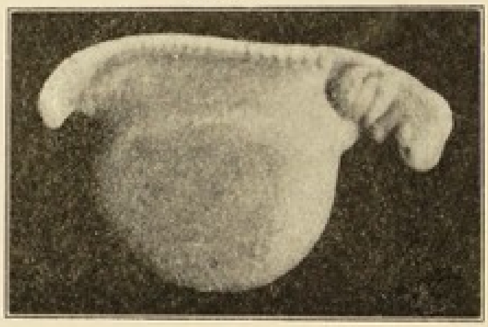
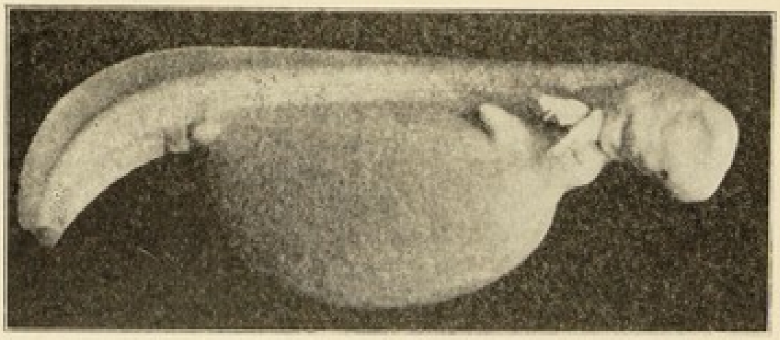


Fig. 67



Figs. 65 to 67.—Embryos of *Cryptobranchus*, showing the gradual formation of the body and the presence of the yolk. (B. G. Smith, in *Journal of Morphology*.)

The gill-slits are completed and the water taken in at the mouth passes through them to the exterior. In the meantime internal gills are formed and the external ones disappear. As soon as the external gills are absorbed, a fold of skin grows from the side of the head to cover the gill-slits, leaving a small opening, the spiracle. This fold of skin is the operculum. The hind limbs appear first, the tail is gradually absorbed, front limbs break through the skin

Fig. 68

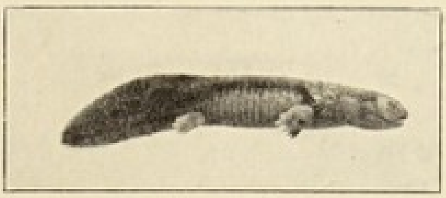


Fig. 69

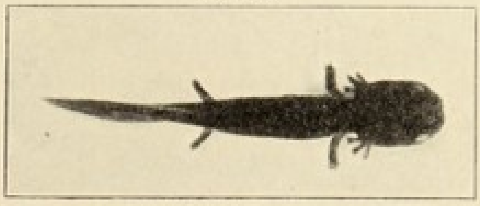
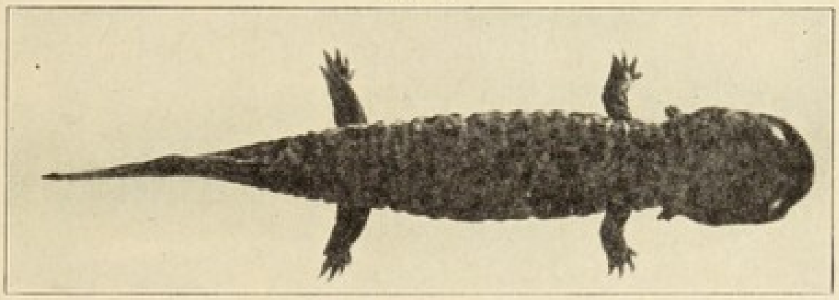


Fig. 70



Figs. 68 to 70.—Fig. 68, larva of *Cryptobranchus* two months after hatching; Fig. 69, ten weeks after hatching; Fig. 70, larva one year old. The newly hatched larva retains a supply of yolk sufficient to last it from two to four months. Pulmonary respiration is established about five months after the hatching period. The metamorphosis takes place at the end of the second year. Sexual maturity is attained, probably at the end of the fourth year. (B. G. Smith, in *Journal of Morphology*.)

and the tadpole becomes a frog. There are important and interesting internal rearrangements accompanying these external changes. The series of changes by which the tadpole is transformed into a frog is known as metamorphosis.

CHAPTER VIII

HYDRA—AN ANIMAL MADE UP OF TISSUES ONLY

LABORATORY STUDY.—Examine the living *Hydra* in a watch-glass and work out its structure, tentacles, hypostome, mouth, base, ectoderm, endoderm, buds, testes, ovary. Feed *Hydra* with small bits of meat or filter paper which has been soaked in meat juice and describe the process of eating. Study the normal activity of *Hydra*, response to jars, and mechanical stimulation. Such hydroids as *Pennaria* or *Obelia* may be used in place of *Hydra*.

Kinds.—There are two common species of hydra that are abundant in fresh water streams and ponds. One is bright green, due to the presence of innumberable chloroplastic corpuscles, which gives it the name *Hydra viridis*. The other species is of light brown color, due to the presence of yellowish corpuscles, and is known as *Hydra fusca*. *Hydra fusca* is much larger, otherwise the two are very similar. Hydra can easily be seen in an aquarium jar attached to the side nearest the window. They vary in length from 2 to 20 mm.; this is largely due to the fact that the body is capable of great expansion and contraction. The hydra represents a small group of animals in which the absence of well defined organs made up of tissues such as are found in the frog is a conspicuous characteristic. Nevertheless, they are able to do all of the essential things that the frog does to maintain existence. They have been studied for many years as representing the simplest of the many-celled animals.

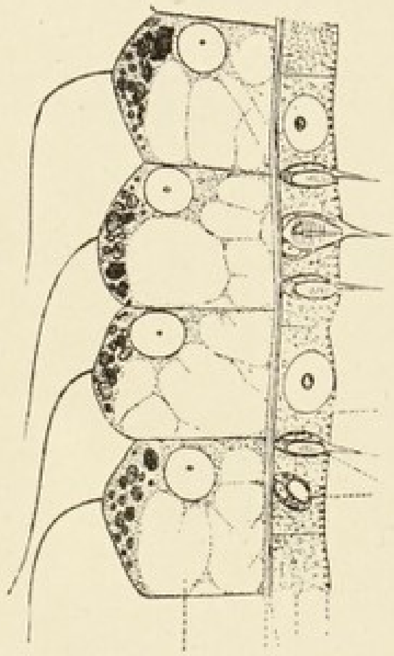
Morphology.— In general shape the body is a cylindrical sac attached at one end, which is the foot or basal disk. The foot is not permanently fixed but adheres partly through the action of adhesive gland cells and partly by forming a vacuum. The mouth is somewhat star-shaped and is on the distal end, situated on the top of a conical elevation, the hypostome. Tentacles arise from the body at the junction of the body wall and hypostome and vary on *Hydra viridis* from four to twelve and on *Hydra fusca* from six to ten. They are capable of great expansion as they move independently about searching for food and capturing it.

Food.—Hydra is more or less carnivorous, sometimes devours algæ, etc., but feeds especially on the small water fleas which are seized by the tentacles and drawn into the mouth. The mouth opens and the daphnid is slowly swallowed and passed into the digestive cavity. The indigestible parts are afterward expelled by way of the mouth. Within the body of the hydra there is a single cavity which communicates directly with the hollow tentacles. This cavity must serve for digestion and circulatory work, and hence is termed the gastrovascular cavity or enteron.

FIG. 71

Hydra viridis, with testicles just below the tentacles and an ovary near the middle. (After Hertwig.)

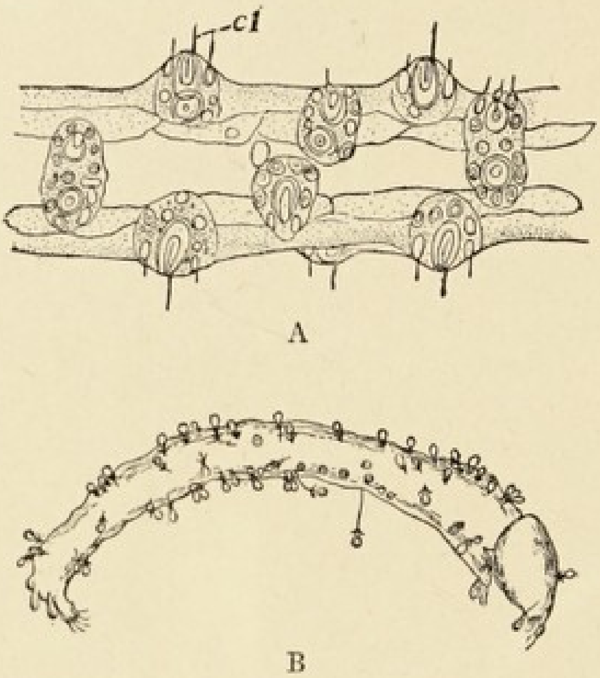
FIG. 72



Section of body wall of *Hydra*. *ek*, ectoderm; *en*, endoderm; *s*, mesoglea; *cn*, nematocysts; *c*, cuticula. (From Hertwig, after F. E. Schulze.)

Structure.—The body of hydra is composed of two layers of tissue: the outer, the ectoderm, and the inner, the endoderm. These two layers are separated by a jelly-like, non-cellular layer, the mesoglea, which appears as a line when viewed in a microscopical section. The ectoderm has no connection with the food cavity, so that these cells are nourished only as food is diffused by osmosis, first passing through the endoderm, and mesoglea. The outer layer of ectoderm serves to protect the hydra and also to act as a generalized sense organ. The protective cells in the ectoderm are the nematocysts which are described below. There are no well defined sense organs such as ears, eyes, etc., yet hydra responds to different degrees of light, jars, touch, etc. There are, however, some specialized cells in the ectoderm which respond to stimuli and are in connection with an indefinite plexus-like layer of cells to which the name nervous system has recently been given. The endoderm cells are longer than the ectoderm and are of two kinds—glandular and digestive.

Fig. 73



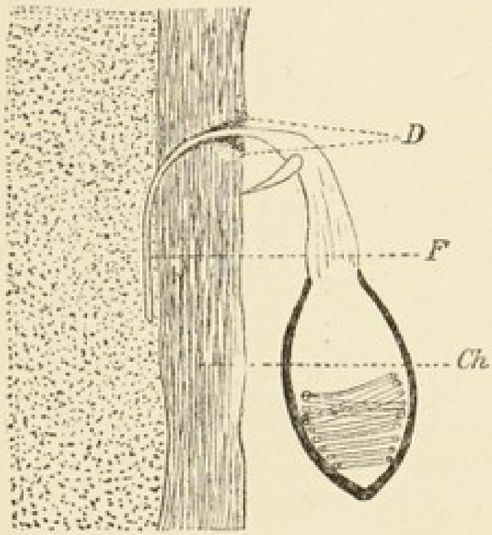
Nematocysts and their action. *A*, portion of a tentacle showing the batteries of nematocysts; *cl*, cnidocysts; *B*, insect larva covered with nematocysts as a result of capture by *Hydra*. (From Jennings.)

Nematocysts.—The whole body and particularly the tentacles are covered with small projections, from the surface of which are stiff hairs. Each hair is connected with a highly differentiated cell termed the nematocyst or stinging cell. The stiff hair on the surface is called a cnidocil or trigger hair, because when this hair is brought in contact with a water flea, the effect is to cause the nematocyst to discharge a long thread, which penetrates the prey, causing paralysis. The fluid which is contained in the undischarged nematocysts is a poisonous secretion. When a stinging cell has been once discharged, the thread cannot be withdrawn and so is useless to the hydra and a new nematocyst must grow from the underlying cells to take its place (Figs. 73, 74, and 75).

Reproduction.—Reproduction in all of the hydras may take place in two ways—the asexual and sexual.

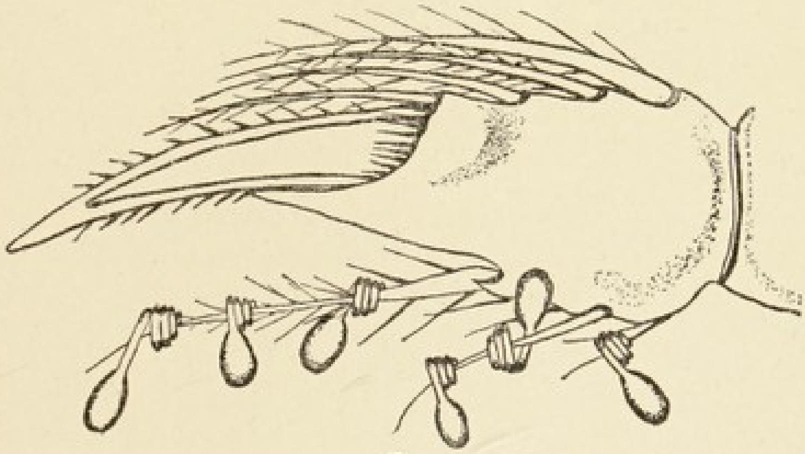
Asexual Method.—The asexual process consists in the formation of a new hydra without fertilization. The usual method is the growth of one or more buds which first appear as slight bulges in the body wall. These gradually grow in length, small tentacles

Fig. 74



A

Fig. 75

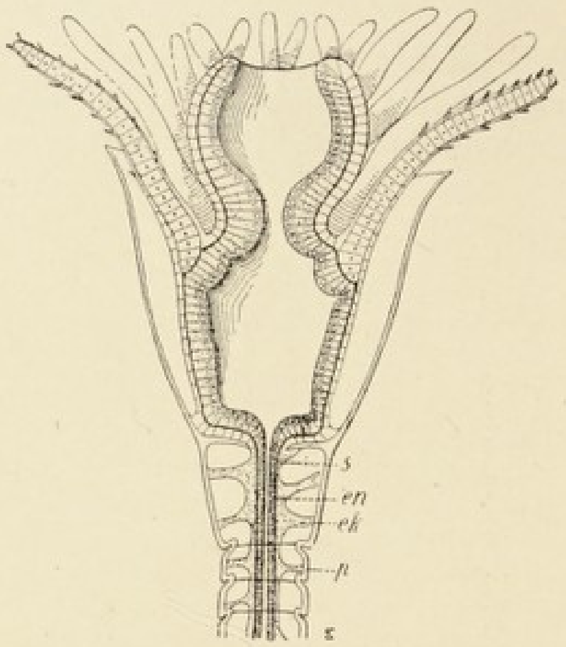


B

Figs. 74 and 75.—The action of nematocyst. Fig. 74, a nematocyst piercing the chitinous covering of an insect; Fig. 75, nematocysts holding a small animal by coiling about its spines (After Toppe, in *Zoöl. Anz.*)

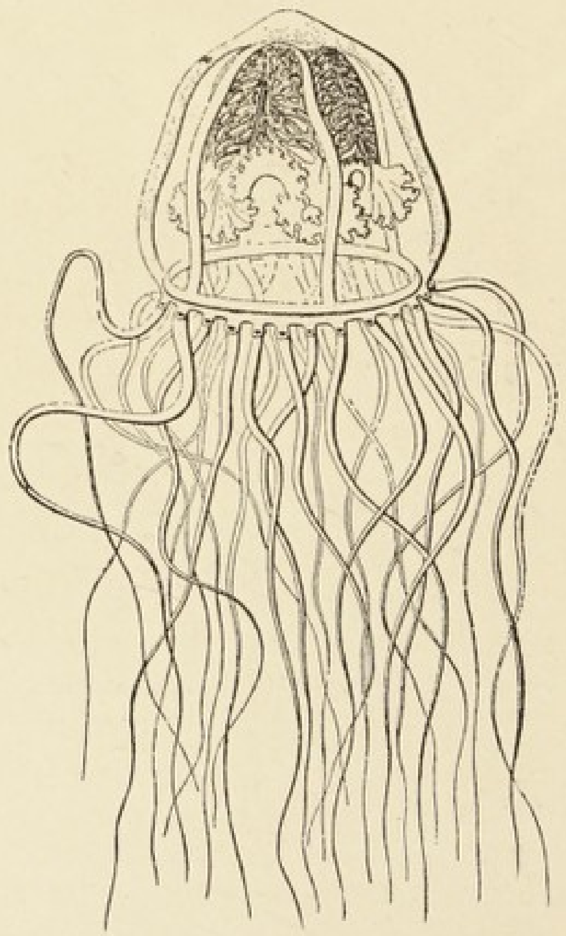
arise on the free end and a mouth appears. During all of this time the gastrovascular cavity of the parent is connected with that in the bud. The rate of growth is largely determined by the amount of food which the parent hydra secures. After a time the bud becomes

Fig. 76



Section through the hydranth of *Campanularia geniculata*. *ek*, ectoderm; *en*, endoderm; *s*, mesoglea; *p*, perisarc. (After Hertwig.)

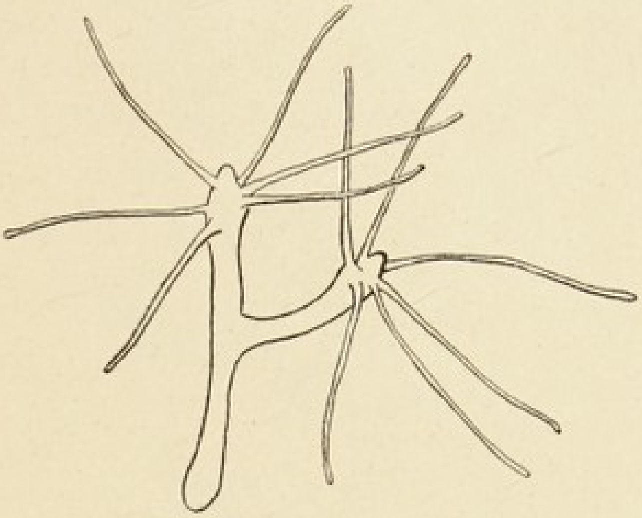
Fig. 77



Tiara pileata. (From Hatschek, after Häckel.)

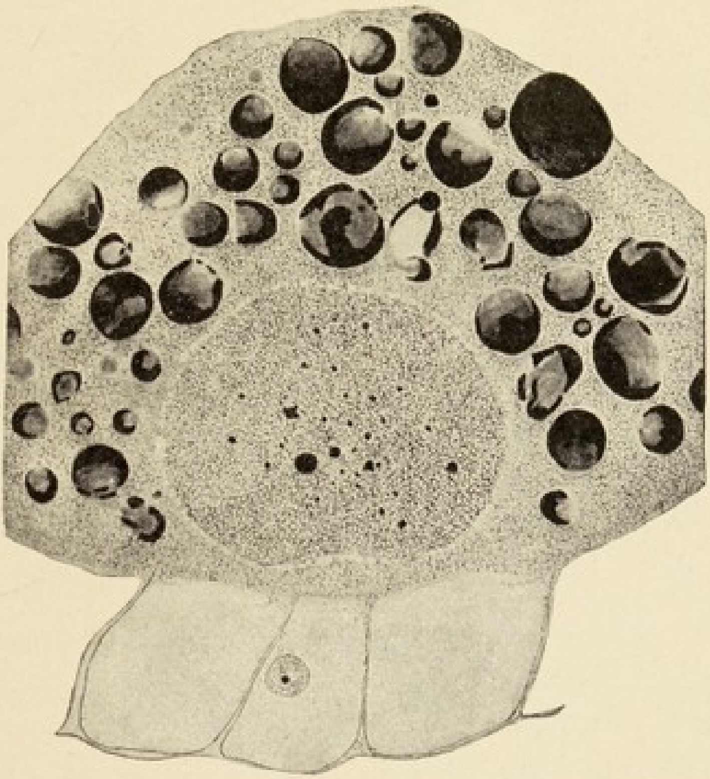
detached from the parent and leads an independent existence, it is like the parent in all particulars except size and possibly in the

FIG. 78



Hydra reproducing by longitudinal division. (After Koelitz, in *Zool. Anz.*)

FIG. 79

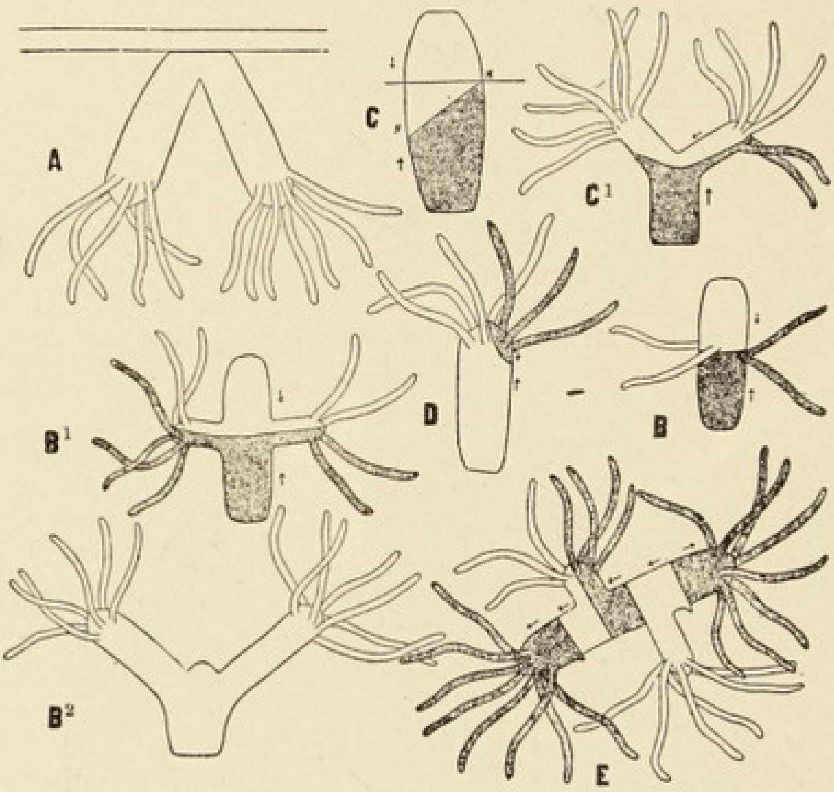


The egg of *Hydra* at about the time that it breaks through the ectoderm and previous to maturation. The nucleus at this time stains lightly, and the pseudo cells, the remains of the young eggs that have been engulfed by this egg, appear as irregular dark bodies in the cytoplasm. (After Wager.)

number of tentacles. There is also evidence to show that hydra may divide longitudinally as shown in Fig. 78.

Sexual Method.—The sexual method of reproduction takes place through the union of definite sperm and egg cells. The sperm cells are found in small conical, whitish elevations a short distance below the tentacles. When the sperm cells are set free in the water, they may continue active for two or three days. The egg begins to grow

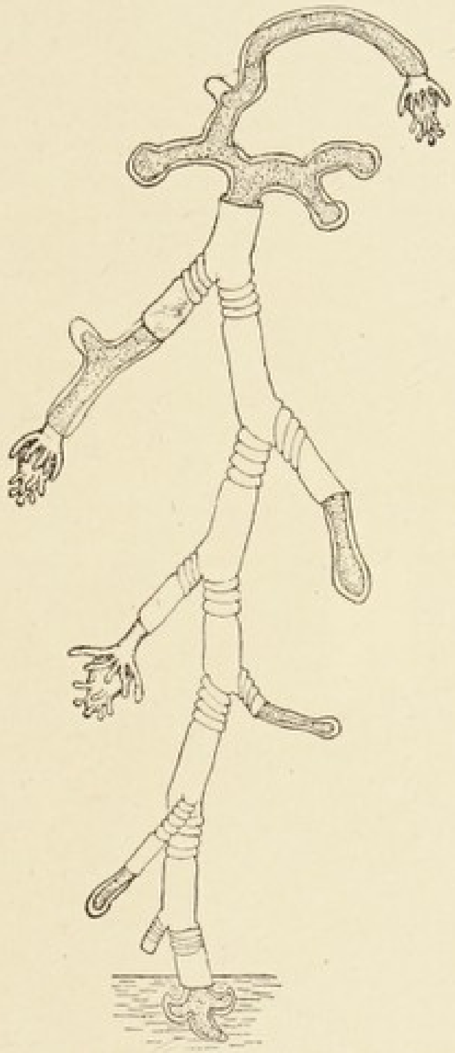
Fig. 80



A, *hydra* split in two, hanging vertically downward; later, the halves separated completely; *B*, two posterior ends united by oral surfaces; B^1, same, it regenerated two heads, each composed of parts of both pieces; B^2, absorption of one piece leading to a later separation of halves; *C*, two posterior ends united by oblique surfaces; later, one piece partially cut off, as indicated by line; C^1, later still, two heads developed; *D*, similar experiment in which only one head developed; *E*, five pieces united as shown by arrows; four heads regenerated, one being composed of parts of two pieces. (King.)

from one of the small ectoderm cells and gradually increases in size through the engulfing of the surrounding cells. The nuclei of these eaten cells remain for some time in the egg cytoplasm (Fig. 79). Usually but one egg cell reaches maturity. When the egg is mature it undergoes maturation in a manner similiar to that described for the frog's ovum, after which the egg is exposed by the breaking down of the outer ectoderm cells. Fertilization takes place as soon as a sperm cell penetrates the cytoplasm, usually within a couple of hours. Segmentation follows in a regular manner until the embryo is hatched. The embryo leaves the parent and remains inactive for some time before it becomes transformed into a hydra.

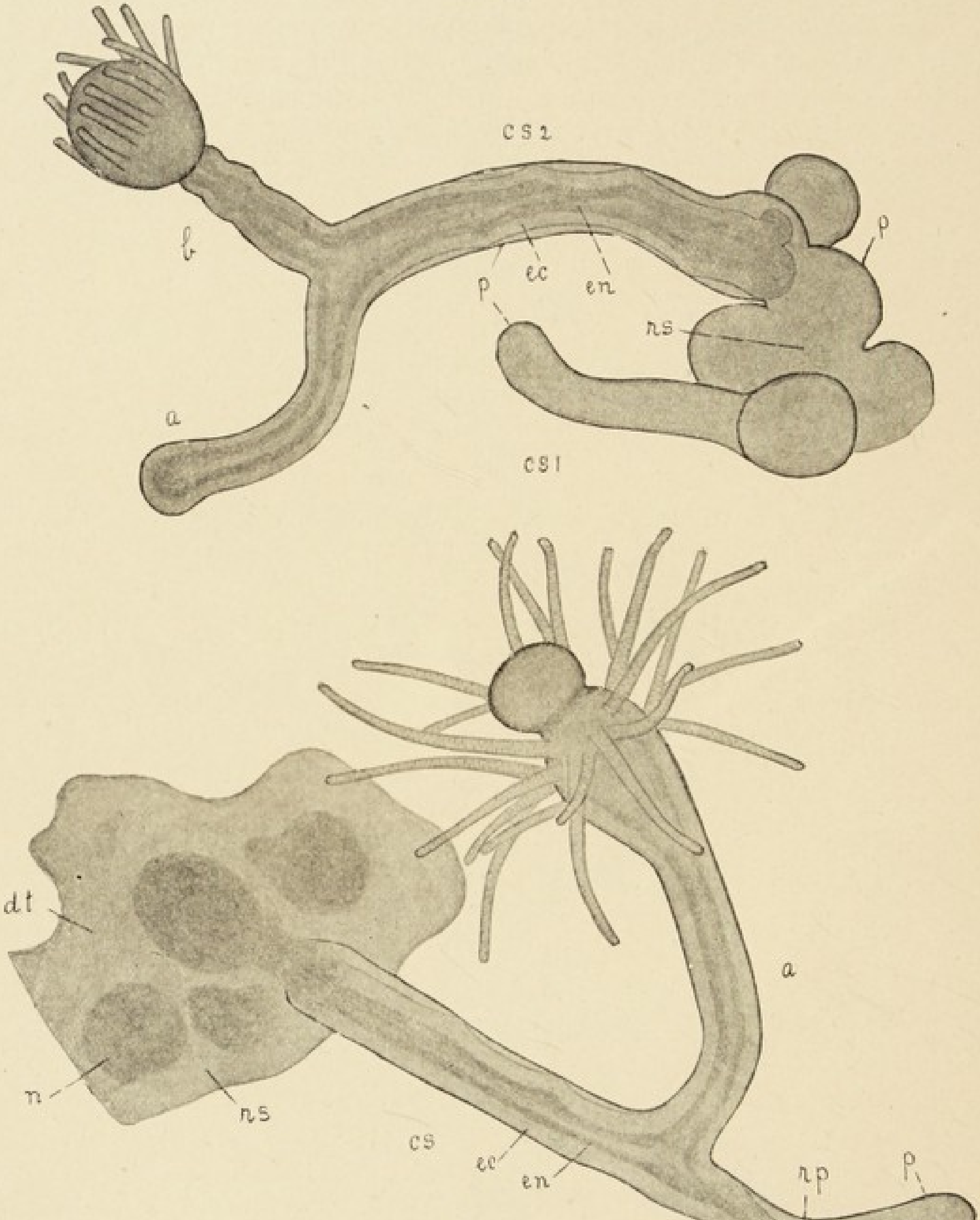
Fig. 81



Pennaria anchored to the bottom of the dish by the distal end, showing regeneration. Unshaded portion is the old stem. (G. T. Hargitt.)

Regeneration.—Closely associated with the origin of a new hydra, especially by the asexual process is the power of regrowing parts that have been lost through mutilation. Hydra can be cut into two parts and each part will regrow the part lost. Closely related to regeneration is the ease with which two hydra may be grafted together. This can be done in a variety of ways often resulting in many headed forms. These cells of the hydra retain the primitive

Fig. 82



After the hydroid has been chopped into small pieces, it is strained through gauze. The hydroid flesh streams through the pores of the gauze and falls into a dish as a fine sediment. This sediment consists of the cells of the body of the hydroid variously dissociated. This figure shows the amount of regeneration that took place in six days in *Eudendrium*. *n*, nodule of living tissue; *ns*, general mass; *cs*, outgrowth which has divided and produced a hydranth on one branch; *ec*, ectoderm; *en*, endoderm; *p*, perisarc of outgrowth; *rp*, regeneration point. (H. V. Wilson, in *Journal of Experimental Zoölogy*.)

power of growth although they have taken up definite positions in the organism and their usual work is not that of reproduction.

Physiology.—In a general way it may be said that hydra carries on all of the physiological functions of a more complex animal like the frog. It is a definite organism living in a specific environment to which it is well adapted. It secures food and leaves progeny, responds to stimuli, and captures more complex animals than itself; and yet one cannot define any structure in its body as an organ in the sense that the word was used in connection with the frog. Differentiation has not yet reached the organ stage in hydra but is rather in the tissue stage.

CHAPTER IX

PROTOZOA—ANIMALS MADE UP OF CELLS ONLY

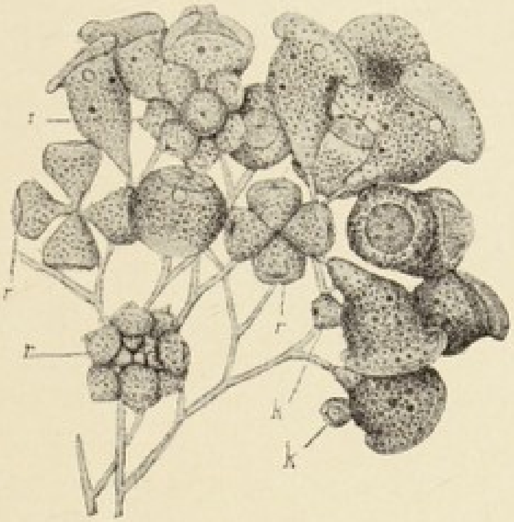
Laboratory Study.—This chapter may be well illustrated in the laboratory by any of the common protozoa, as the purpose is to study unicellular organisms. Paramecium is probably the commonest and most easily obtained. Study the size and shape of the whole animal. Compare several. Notice how it swims. Distinguish the anterior, posterior ends. Locate vestibule. Study cilia, method of feeding; food, water, and contractile vacuoles, etc.

Unicellular Animals.—The whole animal kingdom may be divided into two groups. These two groups stand out very clearly, although there are intermediate forms. They are designated the unicellular and multicellular, or *Protozoa* and *Metazoa*. All of the familiar animals, including the two just studied, the frog and the hydra, belong to the many-celled group. In these animals the cells are arranged in tissues and organs, while in the *Protozoa* the single cell represents the complete animal.

Habitat.—All unicellular animals are aquatic and are found in both fresh and salt water. They are not universally distributed, swarming in every drop of water, the clear water of daily use will usually show but faint traces of living things; but stagnant, muddy or pond water will probably be teeming with life. How did these forms get into the water? Some were blown about in the air and thus were brought to the water, others were attached to pieces of sticks and bits of grass and were then blown into the water to become active. If the pond is one that dries up for a period, these unicellular forms of life may undergo a period of quiescence until suitable moisture is available. Because of their remarkable powers of reproduction it does not take very many representatives to people a pond with millions of *Protozoa*.

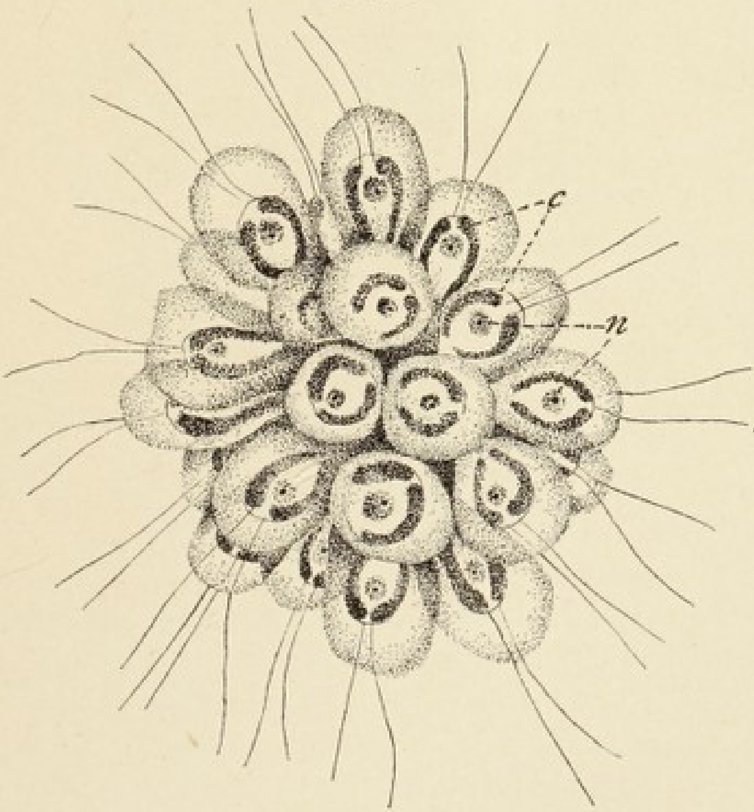
Colony.—Most unicellular animals live alone, by which is meant that they are not attached to one another. In the process of reproduction it often happens in some species that the newly-formed animal does not completely separate from the parent, but remains attached for a time. In this way many animals are often found united, and such an arrangement is termed a colony. As a rule, in a colony all of the cells are alike, each cell being exactly like every other cell as to shape, size, and physiological activity. In a case

Fig. 83



Epistylis umbellaria. *r*, formation of microgametes; *k*, the microgamete fusing with the macrogamete. (From Hertwig, after Greeff.)

Fig. 84

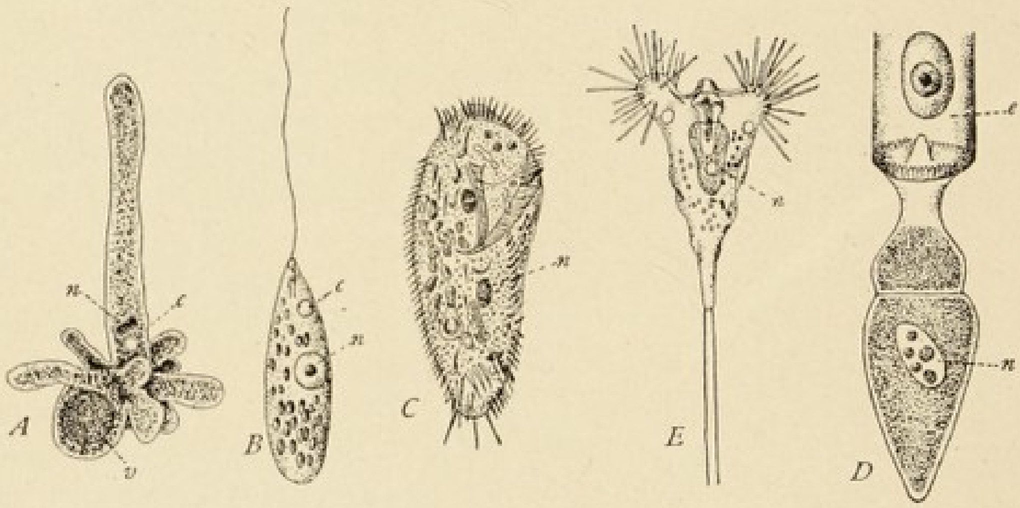


Synura uvella, a colony of phytoflagellates, often a source of disagreeable odors and tastes in drinking waters. (After Calkins.)

where there is some difference, it is found that certain cells become specialized for reproductive purposes, differentiation does not reach a high stage of development although there may be some indication of a higher grade of individuality, some of the various cells merge to a certain extent their individualities into that of the colony and become somewhat dependent for existence on the coöperation of their fellows (Figs. 83 and 84).

Morphology.—The *Protozoa* vary in size when adult from less than one one-thousandth of an inch to three-quarters of an inch in diameter, the most of them are microscopic and some are believed to be ultramicroscopic. The *Protozoa* are spoken of as being the smallest bit of undifferentiated animal matter that is known to

Fig. 85



Types of protozoa. *A*, *Ameba proteus*, a rhizopod (after Calkins); *B*, *Peranema trichophorum*, a flagellate (after Bütschli); *C*, *Stylonychia mytilis*, a ciliate with specialized cilia (after Bütschli); *E*, *Tokophrya quadripartita*, a suctorian (after Bütschli); *D*, *Pyxinia*, *sp*, a polycystid gregarine with primite and deutomerite (after Wasielewsky); *c*, contractile vacuole; *e*, epithelial host cell; *n*, nucleus; *v*, food vacuole.

have independent existence. This does not mean that as animals they are structureless. The cytoplasm itself is divided into two parts in most *Protozoa*. The first is an outer, clear, denser layer known as the ectosarc. This is the part of the animal that comes in contact with the outer world. This layer may be modified and bear on its outer surface numerous prolongations known as cilia, the cilia are for locomotion chiefly and are variously modified as to number, length, and size. The part within the ectosarc is known as the endosarc. It consists of a clear basis and innumerable granules differing in character in each species.

Vacuoles.—Three kinds of vacuoles are found in the cytoplasm of *Protozoa:*

1. *Water Vacuoles.*—Water vacuoles, which look like round cavities lying in the cytoplasm; they are filled with water and are carried about in the cell by the movement of the endosarc.

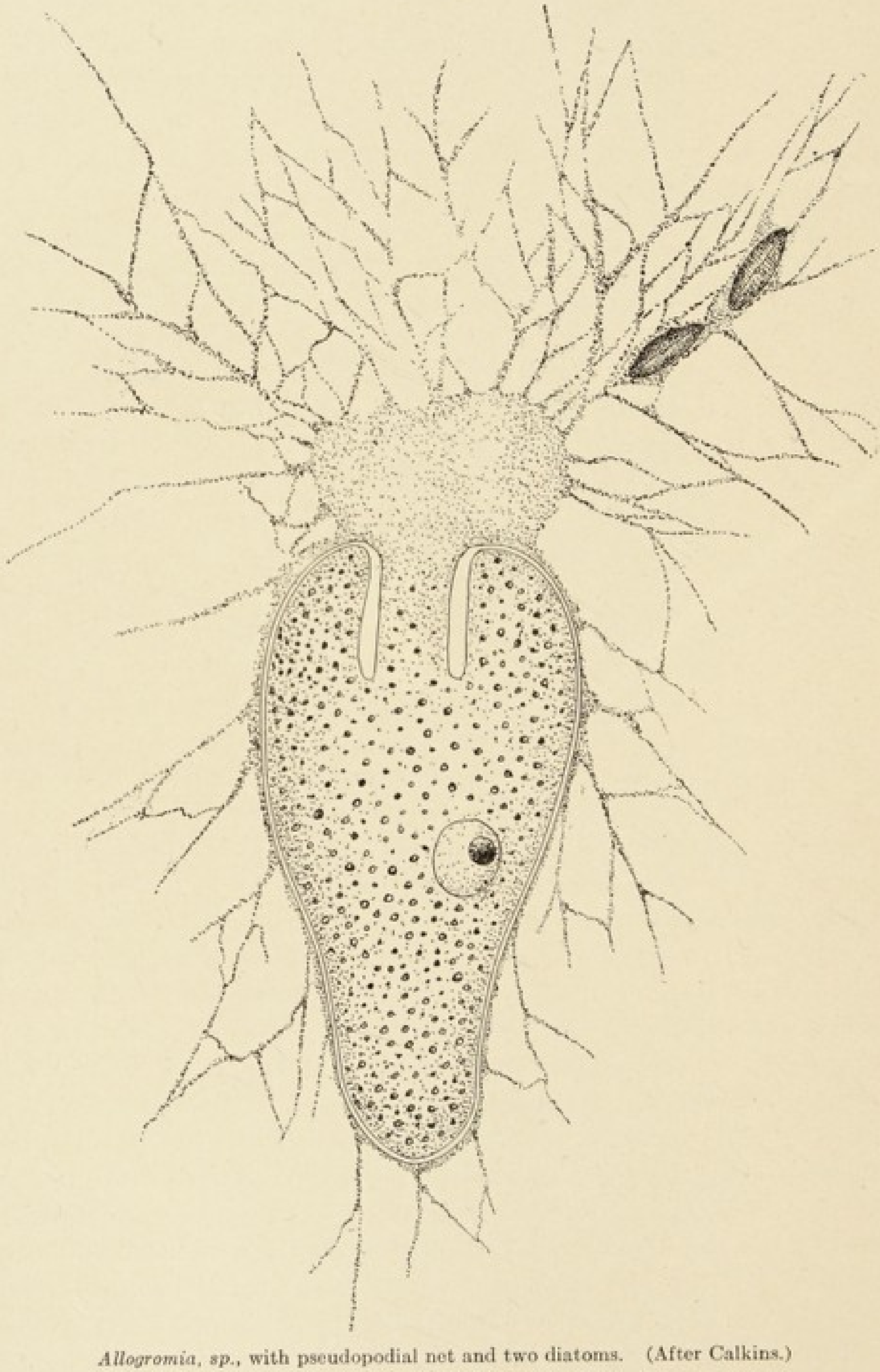
2. *Food Vacuoles.*—Food vacuoles, containing the solid food matter that has been engulfed; within them digestion takes place. When this process is complete these vacuoles approach the ectosarc and the undigested contents are cast off from the body usually at some definite spot.

3. *Contractile Vacuoles.*—Of these there may be more than one. In appearance they look like water vacuoles but are much larger and have a definite position in the cell. The contractile vacuole is chiefly distinguished from the other vacuoles by its more or less rhythmical pulsations. During the time when the vacuole is expanding it slowly fills with liquid which drains in from the surrounding cytoplasm. The contraction takes place quickly and the contained liquid is forced to the exterior.

Nucleus.—The nucleus is present in one form or another in all *Protozoa.* It does not have any definite position in the cell nor a constant shape. The *Protozoan* nucleus assumes a more dense appearance than most of the nuclei in multicellular animals. The numerous chromatin granules are held together by a firm nuclear membrane and have the appearance of being solid in the usual preparations. There may be more than one nucleus or there may be several hitched together, chain-like as in stentor. In many cases the nucleus consists of two distinct parts—a larger, known as the macronucleus, and a smaller, micronucleus. In a strict morphological sense it is not always possible to make out a nucleus, yet experts claim that the chromatin granules can always be found, and these are regarded as the essential structures to be present in defining a nucleus (Figs. 87, 88, and 89).

Physiology.—The manner in which these simple organisms are nourished, grow, and reproduce, furnishes a valuable comparison with the higher animals. Morphologically composed of but a single cell, yet physiologically able to do the work of a complex organism, they are adapted to their environment as perfectly as any animals, although more plastic and primitive. The *Protozoa* contain no special sense organs which enable them to distinguish between nutritious and non-nutritious substances; yet they readily engulf the former and reject the latter. Their food consists of proteins, carbohydrates and fats taken in the form of minute plants, other *Protozoa*, and organic debris. These several substances must be

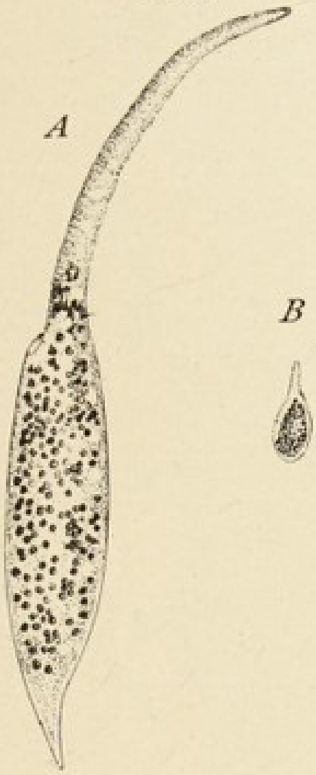
Fig. 86



Allogromia, sp., with pseudopodial net and two diatoms. (After Calkins.)

digested as in the higher animals; here the digestion is believed to take place in the food vacuoles.

Fig. 87



Dileptus, sp. Two sister cells. *A*, normal individual with macronucleus in form of scattered chromatin granules (chromidia); *B*, individual starved for several days. From photographs taken with same magnification. (After Calkins.)

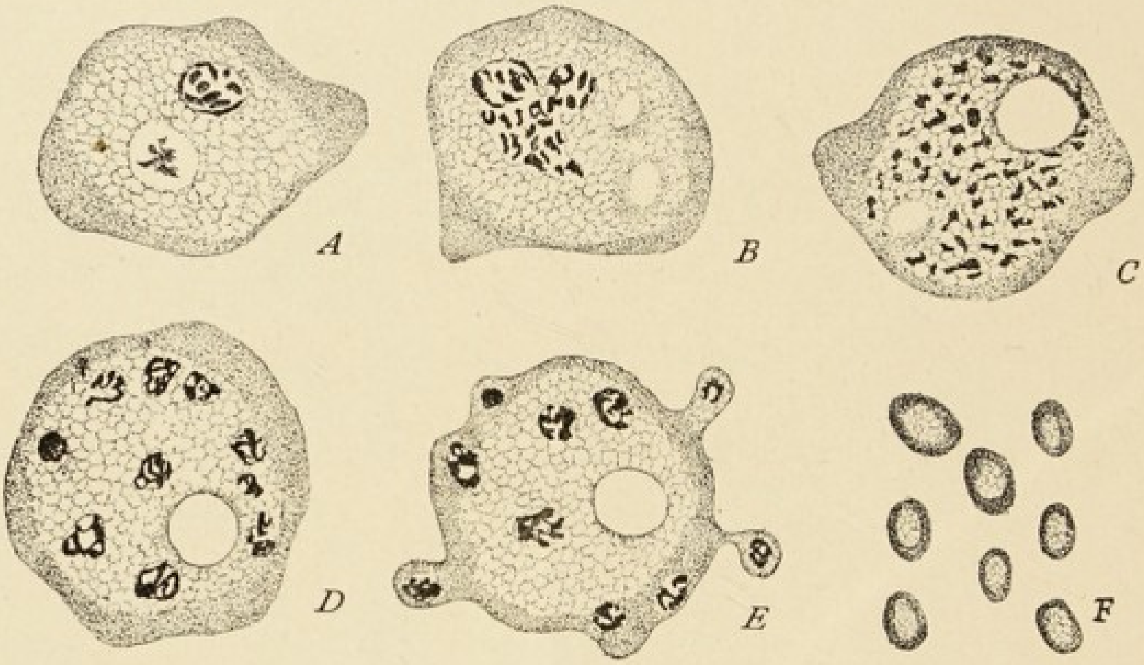
Fig. 88

Dileptus, sp., with distributed nucleus in process of division. Each of the chromatin granules is drawn out in the form of a rod and divides. (After Calkins.)

Reproduction.—*Fission.*—The predominationg method of reproduction is an asexual process. This is evidenced by the fact that Woodruff has been able to observe three thousand generations of paramecia in which the asexual method has been the exclusive form of reproduction. In this process the nucleus is constricted into equivalent parts, followed by a corresponding division of the cytoplasm. The result is that two *Protozoa* are derived from the parent, which thereby merges its identity into that of the two new individuals. The term fission is given to this method of reproduction. When fission is not equal, as sometimes occurs, the term budding is applied. It also happens that *Protozoa* go into a state of encystment; the body becomes round and the cell wall is much thickened. This is a quiescent state in which the normal activities are wanting.

Before the protozoan comes out of the encysted state the cell contents become many times divided by repeated fission. Encystment is usually induced by some adverse conditions in the immediate environment which are of a temporary nature.

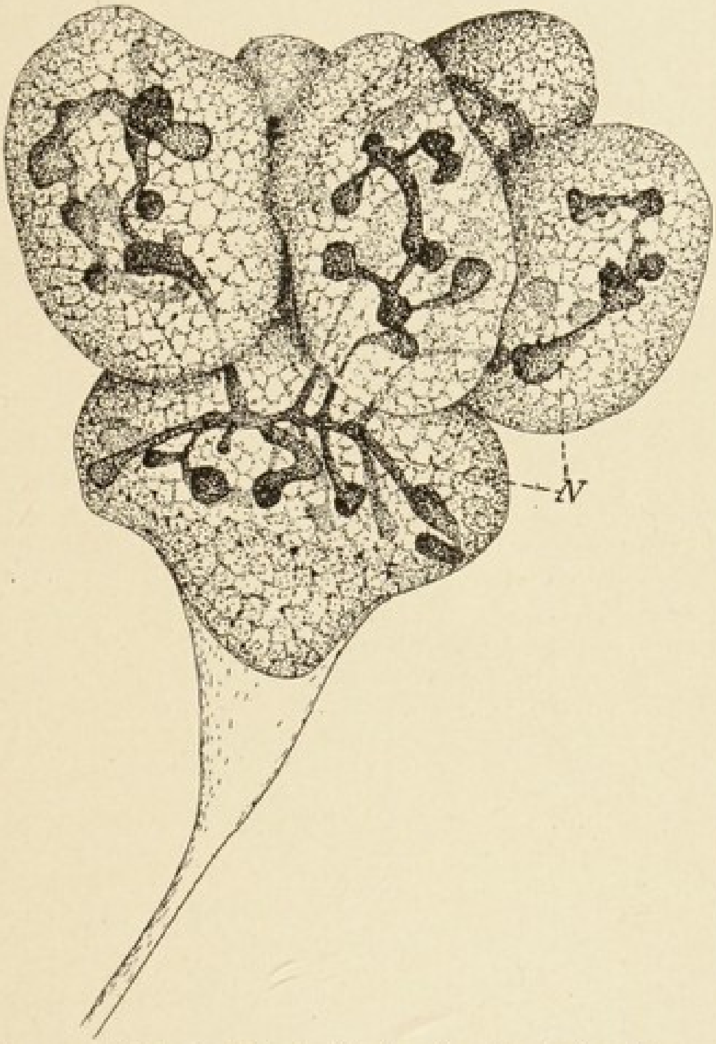
Fig. 89



Entamœba histolytica. *A*, organism showing rods and granules of chromatin in the nucleus, vacuole with some stained substance, and dense ectoplasm; *B*, the chromatin of the nucleus passing into the cell plasm, where it is distributed as chromidia, shown in *C; D*, aggregation of chromidia to form secondary nuclei; *E*, "spore formation" by budding; *F*, spores of *Entamœba histolytica* as seen in feces. (After Craig.)

Conjugation.—In many forms of *Protozoa* extended observation reveals that there are periods when fission is marked by a high rate of division and conjugation does not occur. This has been called the period of youth. "After some time usually when the rate of division has begun to decline, the protoplasm of the cell body changes slightly in physical and chemical make-up, so that two or more cells upon meeting fuse and conjugate," which marks the period of maturity. There is no definite limit to the period of maturity. The details of conjugation may be omitted from this account. In conjugation two individuals come in contact and unite by a continuous bridge of cytoplasm. As soon as the union is effected, the nuclei pass through a complicated series of changes (Fig. 91) in which the macronucleus of paramecium degenerates and the micronucleus passes through a series of divisions that are similar to maturation in higher animals with the result that one of the minute nuclei wanders across the bridge of cytoplasm. Each cell receives a wandering nucleus which fuses with a similar nucleus but one that is slightly larger. The result is the formation of a fertilization nucleus. The conjugating paramecia separate. The real significance of this process is not fully determined, although the result is variation in the descendents.

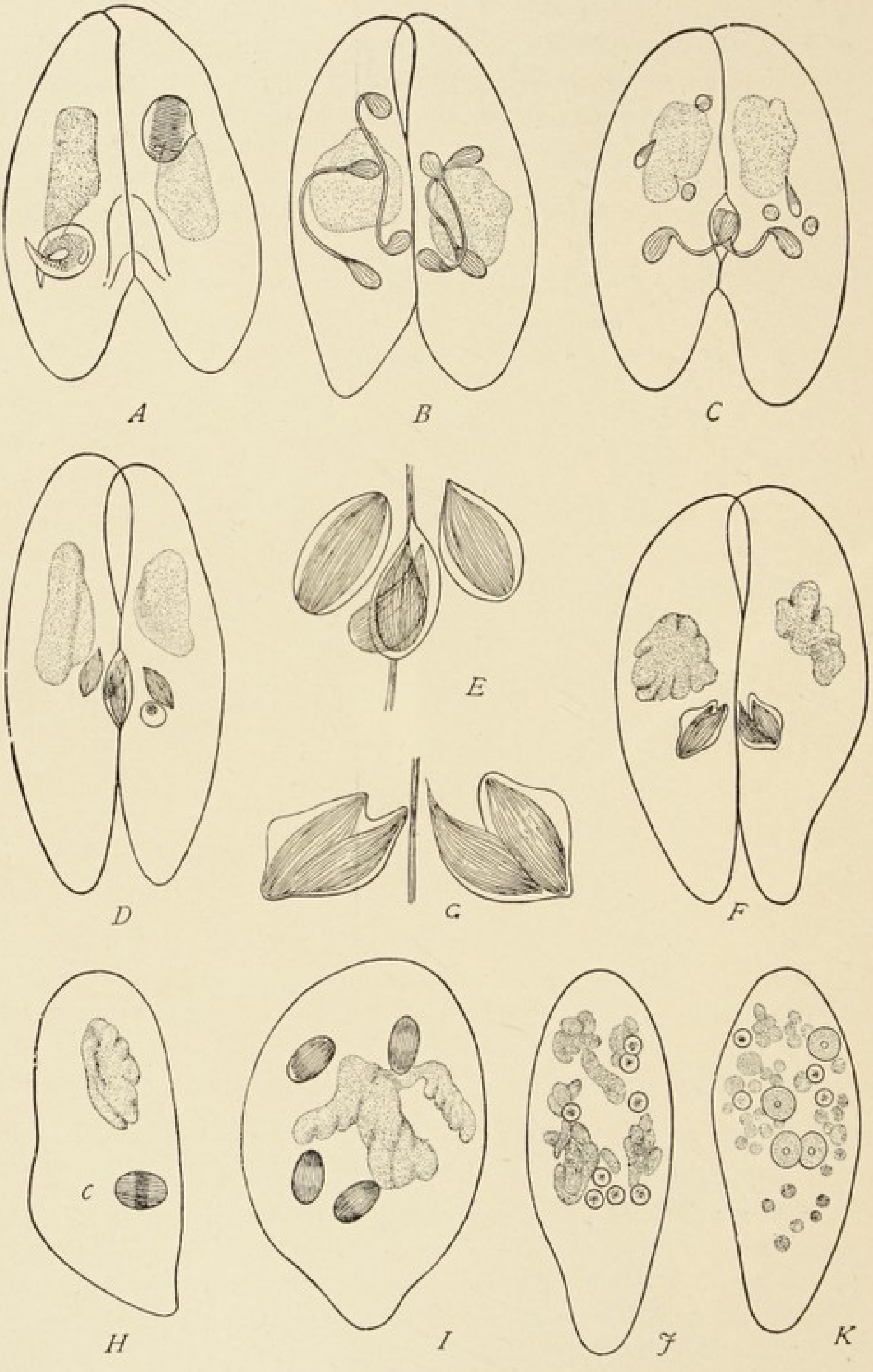
Fig. 90



Ephelota butschliana, a budding individual with five daughter buds. *N.* macronucleus, which forms a branching organ connected throughout. (After Calkins.)

Protozoön Animals.—This study has served to show how an animal composed of a single cell may carry on all of the necessary activities of the complex animal. It is an organism without any of the morphological structures which go to make up the body of the frog. The whole life is lived within the limits of a single cell. "A protozoön rarely retains its individuality more than a few hours. It then

Fig. 91



Conjugation of *Paramecium aurelia*. (After Calkins.)

divides in two, or, in some cases, into a large number of daughter individuals. The parent organism has not died, there is no unicellular corpse, but the protoplasm of which that organsim was composed is now distributed among two or more individuals. We cannot speak, therefore, of the life cycle of an individual protozoön, but must consider rather the protoplasm of which the individual is composed. It is this protoplasm that goes on through generation after generation of individuals, and through all the phases that constitute the aggregate of phenomena which has been termed the life cycle." (Calkins.)

CHAPTER X

BIOLOGY OF CELLS

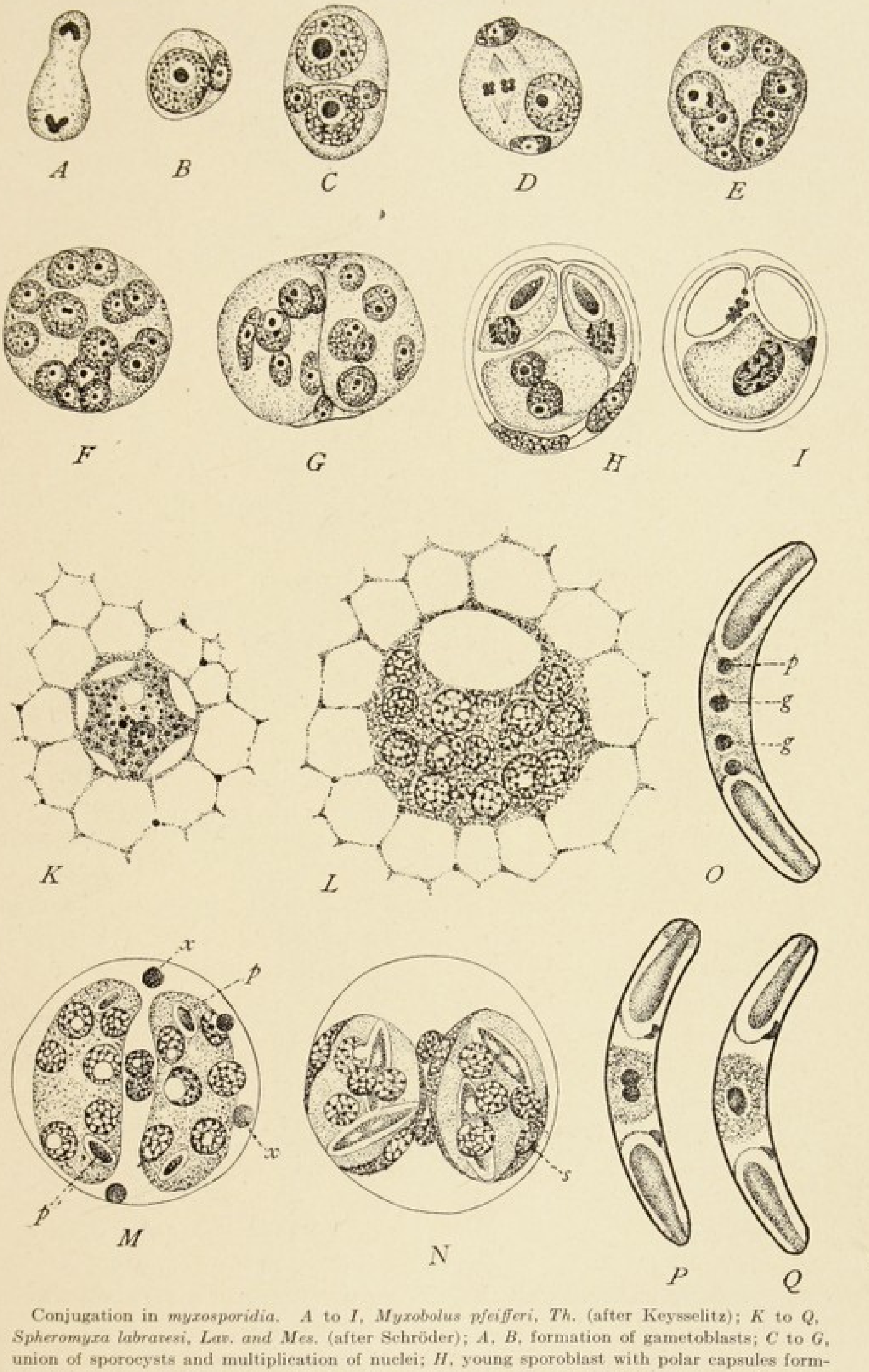
LABORATORY STUDIES.—The work of this chapter may be illustrated in a variety of ways and may well include the *Amœba*, a period on the activities of *paramecia*, the plant cells as represented in *Pleurococcus* and *Spirogyra*. The egg of starfish and the developing ova in the hermaphroditic gland of a *Mollusc* for the parts of the nucleus and deutoplasm. Mitosis and amitosis should be illustrated in such ways as best suit the convenience of the instructor.

CELL THEORY

THE cell theory furnishes the starting point for all modern studies in biology and enables all students to speak the same language. The significance is chiefly in the recognition of the universal similarity in the biological makeup of living things. They all have the cell in common, and the term cell is used as an expression for the active, vital substance, protoplasm. What can the cell do? Under what conditions is its work best done? How does it grow? To what extent are plant and animal cells alike? These and many other questions lie at the basis of our attempts to understand the great problems of adaptation, disease, heredity, sex, evolution; in short, every biological question finds its best answer in a study of the cells involved. Because all plants and animals, great and small, can thus be analyzed into a common structural unit, it is desirable to learn all that one can about their life, especially in the simplest forms of life before differentiation has taken place.

Structure of the Cell.—The laboratory work upon the intestine of the frog and the studies on *Protozoa* and some simple plants all showed that the cell was a definite body easily recognized through the use of the microscope. The result of these several studies can be summarized in attempting to tell the structure of cells. In shape the cell does not follow any definite form but is regulated by the forces that act directly upon it and by the nature of the cell, especially the cell wall. The microscopic *Pleurococcus* and *Amœba* well illustrate this point, for the plant cell *Pleurococcus* is uniformly round,

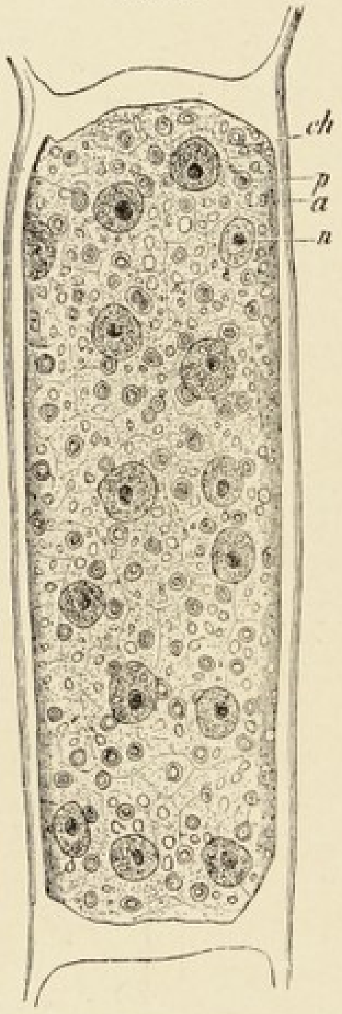
FIG. 92



Conjugation in *myxosporidia.* *A* to *I*, *Myxobolus pfeifferi, Th.* (after Keysselitz); *K* to *Q*, *Spheromyxa labrazesi, Lav. and Mes.* (after Schröder); *A*, *B*, formation of gametoblasts; *C* to *G*, union of sporocysts and multiplication of nuclei; *H*, young sporoblast with polar capsules forming and gametic nuclei not yet united; *I*, spore with capsules (not filled in) and gametic nuclei united; *K*, young pansporoblast of *spheromyxa*, with dimorphic nuclei; *L*, pansporoblast with fourteen nuclei; *M*, pansporoblast divided into sporoblasts, each with two pole capsules (*p*), four globules present (*x*) and with two central reduction nuclei; *N*, sporoblasts having two shell nuclei (*s*), two polar capsules, each with a nucleus and two germ nuclei; *O*, young spore, shell nuclei disappeared, capsule (*p*) and germ nuclei (*g g*) compact and lying in a row; *P*, same, with union of gametic nuclei in the sporoplasm; *Q*, same, ripe spore with polar capsules and sporoplasm.

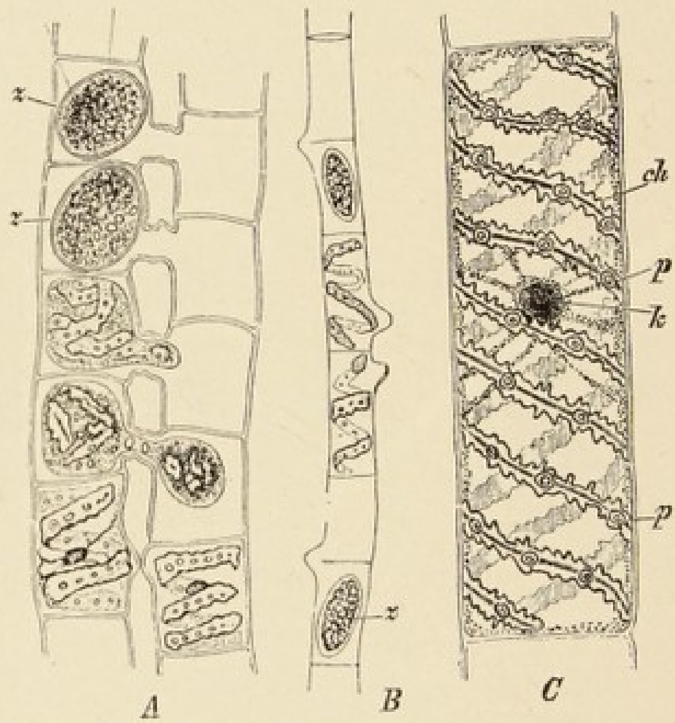
while *Amœba* rarely assumed any constant shape. Both cells belong to the simple forms of organic existence and it would not have been difficult to have found an aquatic unicellular plant for this comparison in which case the water surrounding each would furnish a similar external stimulus, but how different the results. Such com-

Fig. 93



Cell of *Cladophora* showing many nuclei (*n*) in the undivided mass of cytoplasm and various forms of plastides (*ch*, *p*). (Strasburger, Noll, Schenck, and Karsten.)

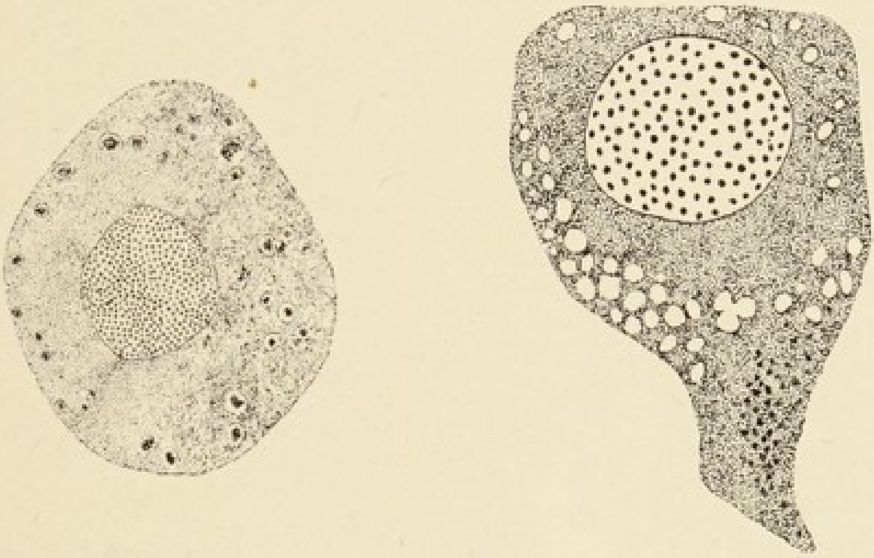
Fig. 94



A, copulation of *Spirogyra quinina; B, Spirogyra longata; C*, a cell of *Spirogyra jugalis; ch*, chromatophore; *k*, nucleus; *p*, pyrenoid; *z*, zygospore. (Strasburger, Noll, Schenck, and Karsten.)

parisons force us to suggest that the very nature of the cell substance must be held in part responsible for the mere shape of cells. The comparison also serves to illustrate that not all cells possess a cell wall, for the *Amœba* is a naked cell. It does not mix with the water and remains a distinct body that carries on all of the necessary activities of an animal. It is important to keep this fact in mind when any attempt is made to explain the so-called mechanics of cell division, for there are a number of cells which do not support a limiting membrane that do grow new cells even in the higher animal, such is the case with the white blood corpuscles.

Fig. 95

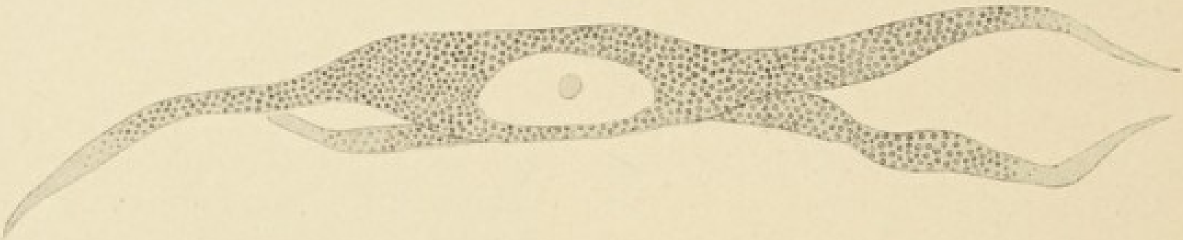


Invertebrate nerve cells showing various bodies in the cytoplasm as well as vacuoles.

Cytoplasm.—The parts of the cell are naturally divided into cytoplasm and nucleus. The cytoplasm presents a widely different appearance even in the cells that have thus far been studied, and the difference would be greatly increased with further study. The ultimate structure of the cytoplasm in most cells cannot be determined because of the presence of bodies which are regarded as passive bodies and to which a variety of names are applied as paraplasm, metaplasm, deutoplasm. These bodies may be minute granules as in the starfish ova or large spherical masses as in the egg of the frog or a mollusc. In the green plant cells the cytoplasm is usually occupied by definite green masses to which the term chloroplasts is applied. Their special work is described in the section Source of the Food of Cells, p. 102.

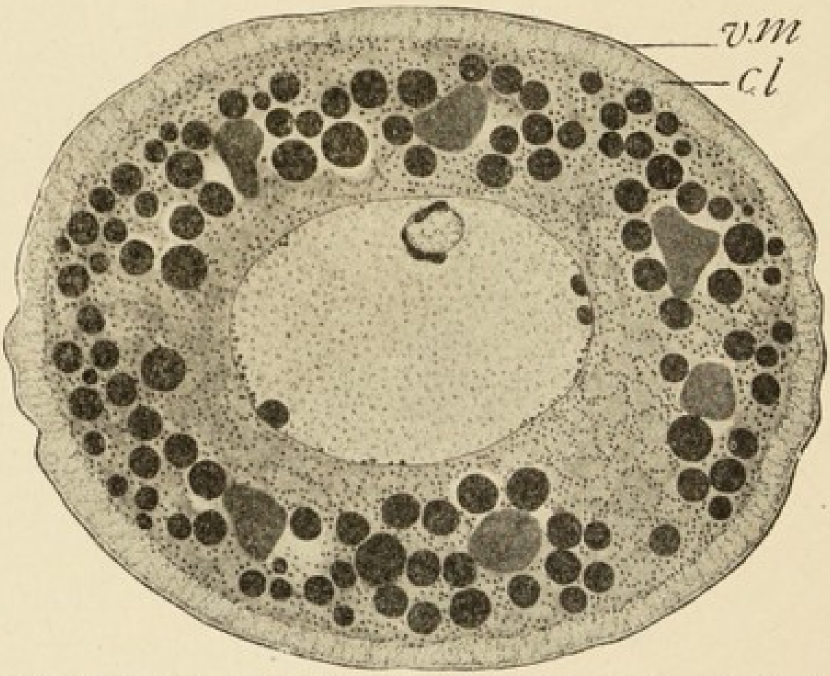
Starches and oils are often found stored up in plant cells in the cytoplasm, while in most nerve cells variously shaped bodies occur which probably represent stored energy. In short, the passive bodies in the cytoplasm usually represent some form of latent energy upon which the cell may draw. As would be expected the protozoa have a number of special structures such as vacuoles that take the place of more complex organs in the higher animals. These vacuoles contain water, engulfed food or waste. In the case of the water and food vacuoles, they are temporary and are formed anew as more food or water is taken into the cytoplasm.

Fig. 96



Dorsoventral parenchyma muscle fibers of *Hemiurus crenatus*. Note the numerous bodies in the cytoplasm. × 1350. (After Lauder.)

Fig. 97



Section of the egg of *Neries*, fixed in Meves' fluid five minutes after insemination. The cortical layer is somewhat reduced. *cl*, cortical layer; *vm*, vitelline membrane. Note the several kinds of bodies in the cytoplasm. (From Lillie, in *Journal of Morphology*.)

Nucleus.—The nucleus of the cell is usually a more or less open meshwork except in the protozoa where the granules of chromatin are closely crowded. In the great majority of the cells there is no difficulty in differentiating the nucleus by the use of suitable stains; in a few microörganisms the chromatin granules are not collected into a distinct mass but are scattered in the cytoplasm. The nuclear membrane is a delicate wall that sharply marks the limits of the nucleus. For the purposes of this study, the more general parts of the nucleus will suffice. The non-dividing nucleus of most cells is divisible into the parts that take a basic stain and those that take the plasma stain. The basic staining structure is the chromatin network which may be gathered into noticeable bodies called karyosomes; and usually one round deep staining body the true nucleolus. The plasma stains reveal the presence of a number of minute granules in the nuclear sap as well as a framework for the support of the chromatin. The term linin is applied to the plasmic staining parts. The variety of appearances of the nucleus consists for the most part in the variation in the amount and arrangement of the chromatin.

Structure of Protoplasm.—Protoplasm constitutes the living part of all cells in plants and animals, and in composition and ways of living is essentially the same in all cells. Does protoplasm have a structural organization that can be applied to all of the known appearances? This is a question which has excited much interest in the past with the result, however, that there is no universally accepted explanation.

1. *Fibrillar Theory.*—The adherents to this theory claim that a distinct meshwork of cystoplasmic fibrils can be made out when suitable treatment is employed and such terms as spongioplasm, reticulum, filar substance, etc., are employed to describe the meshwork. Filling in the meshes there is a structureless sap-like substance. For some cells and for certain phases of cell activity the fibrillar theory adequately describes the structural conditions of the protoplasm.

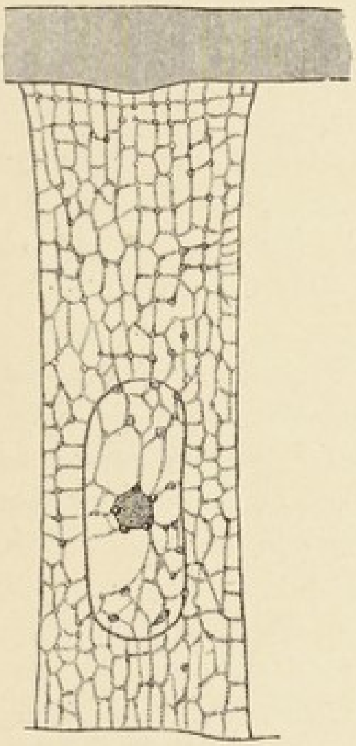
2. *The Alveolar Theory of Bütschli.*—"If we imagine a hyaline protoplasm which is continually manufacturing metaplasmic products and storing them up in its protoplasm, these products will be deposited as spherules gradually increasing in size, so that the protoplasm, between them will be converted into alveolar partitions between the droplets. In many an egg cell, where there is a growth of protoplasm from this building up of food into reserve materials, the development of such an alveolar structure can be followed in the living protoplasm, and such cells when mature show a marked alveolar structure whether examined in the fresh or in the hardened and stained condition. Such a protoplasm would be practically an emulsion of one fluid in another, and according to Bütschli, artificial emulsions, made by mixing rancid oil with sodium carbonate solu-

tions, may show under the microscope a very close resemblance to cell protoplasm, and may even exhibit ameboid changes of form in consequence of the diffusion currents set up at the surface of the drop between its contents and the surrounding water." (Starling.) See Fig. 98.

Protoplasm a Solid or Liquid.—The answer to this question becomes of importance when one attempts to explain the physical conditions of protoplasm. The observations on *Amœba* and paramecium must have shown that the protoplasm is mobile and a similar condition is found in some plant cells; yet the cell is organized, has a definite shape and power to resist pressure, etc, and these are qualities that one associates with solids. The continued existence of protoplasm in water shows that the outer layer must be in some way modified to form a distinct surface separating the water from the internal protoplasm. "The superificial layers of the protoplasm must therefore be in a condition of tension and exercise pressure on the internal portions of the cell, which will tend to diminish the surface of the cell to the smallest possible extent, *i. e.*, to bring it into the spherical form. This form is characteristic of free cells in their condition of activity, and the smaller the mass of protoplasm, supposing it to be homogenous, the greater will be the pressure exerted by its surface layer on its contents and the greater resistance will it present to deformation of the spherical form. A fluid drop, if suspended in a fluid with which it is immiscible, will present greater rigidity the smaller its dimensions. Almost any degree of rigidity can also be imparted to larger masses of fluid protoplasm if their interior has undergone chemical differentiation so as to be made up of two or more immiscible fluids arranged as droplets within alveoli, as in Bütschli's theory. In such a case every droplet will present resistance to deformation and every surface will resist penetration or extension. Protoplasm may be regarded as essentially fluid in character, the form and rigidity which are acquired by most cells being due to chemical and physical differentiation occuring in its fluids." (Starling.)

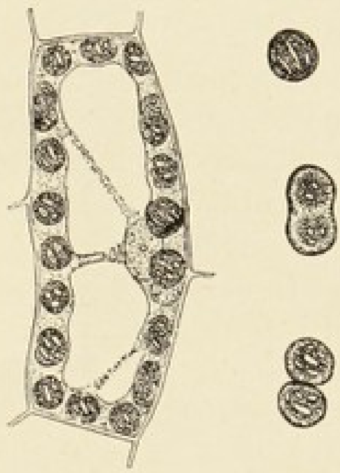
Source of the Food of Cells.—In describing the physiology of the frog it was shown that the frog required food that was already made and in this respect represented the conditions that obtain in all forms of animal cells. If there were not some place where more food could be prepared, it is evident that the time would come when animals would all starve. But this dire calamity is not anticipated as long as green plants continue to grow. In the green plant cells, pleurococcus and spirogyra or the cells of any green leaf, are found a number of spherical masses of chloroplasts. They are organs of the green cells of plants that play a most important role in the life of all. Through the energy absorbed from the rays of the sun as it passes through the chloroplasts carbon dioxide and water are broken down and immediately recombined into a different substance. The first steps in this chemical reconstruction are not known but there soon appears a substance with definite chemical properties which is a stable compound in the form of glucose, a carbohydrate. This

Fig. 98



Epidermal cell of an earthworm. × 3000. (After Hall.)

Fig. 99



Starch appearing as transparent scales in chlorophyll bodies. *A*, chlorophyll bodies lying in the cells; *B*, chlorophyll bodies undergoing division. (From Verworn, after Sachs.)

is followed by starch or some other stable product. The formation of a carbohydrate is the first step in the manufacture of a definite food, and this process is sharply differentiated from the process of nourishment. There is more oxygen in the carbon dioxide and water than can be used in making starch ($C_6H_{10}O_5$) and this oxygen is mostly returned to the air. The making of food while a necessary step does not nourish the protoplasm. The making of carbohydrates is but one step in the production of plant food, there must also be proteins which require nitrogen, sulphur, and other chemicals.

Although the air contains plenty of free nitrogen, this cannot be used by the plant cells in making proteins until it has been combined into nitrate. Usually the nitrates, sulphates, phosphates, etc., are taken up in solution by the roots or in aquatic plants directly from the water into the cells. Through the action of the plant protoplasm the carbohydrates made in the leaf are transformed into proteins of various kinds and this protein synthesis is not restricted to any particular organ in the plant. Fats are also made and stored in the form of oils. The green plant then has the power to make foods out of the chemical elements of the air and water when these chemical elements are properly combined. There is no other known source of food for plant or animal cell. This property of food manufacture is an additional faculty of the green plant protoplasm due to the presence of chloroplasts.

Food of Cells.—The various cells thus far studied have all been busy working in some tissue or as individual units carrying on all of the vital processes. This work requires energy. True, there is a certain amount stored in the cytoplasm of most cells but this soon becomes exhausted unless replenished. The principle of the utilization of energy in living cells has already been adequately dwelt upon in connection with the frog. The real question at this point is, are the conditions alike in plant and animal cells? It used to be thought that the process of food making was a process of supplying energy to the plant protoplasm. It is now maintained and with good effect that the source of all protoplasmic energy is in the food utilized and that the food of the plant cell is just as essentially organic as is that of an animal cell because it is made through the influence of living protoplasm. The plant expends energy and its cells and tissues need to be repaired in the same sense as do the animal cells and tissues. The uses of food then may be said to be the same whether applied to animal or plant protoplasm. The food of the unicellular animals consists of small animals, small plants, and other organic particles that may be in the water; while the food of the microscopic green plant cells consists of carbohydrates, fats, and proteins which have been manufactured within its own protoplasm. The chemical construction of the food then is the same in each instance although the form is distinct. The protein molecule made by plants is so complex that its form is made out with great difficulty as the following shows: the crystalline vitelline of the squash is written $C_{292}H_{481}N_{90}O_{83}S_2$, while the form of the animal protein, hemoglobin is supposed to be about

$C_{712}H_{1130}N_{214}O_{245}FeS_2$. Calcium, iron, silicon, and other minerals are found in various forms of protoplasm and are important parts of the cell's composition and these usually enter in the water and are acted upon by the living protoplasm in the various compounds. Just how this is brought about is not understood.

Assimilation.—The activities of all living cells whether combined into complex organisms or unicellular can be divided into two phases—assimilation and dissimilation. By assimilation is meant all of the changes involved in transforming food into living protoplasm. In all living cells, then, this is a fundamental process the details of which are many and intricate. When the cell does work the immediate source of the energy involved is generally associated with the process of oxidation. To take the place of this utilized energy, the food is digested and gradually transformed into living protoplasm by some steps that are known and by others that remain to be unravelled in the future of scientific research. In the ameba, food is taken in at any place and surrounded by cytoplasm. The food is then acted upon by digestive ferments which render it soluble so that it can actually enter the cytoplasm and be built up into living protoplasm. "In the vast majority of living organisms the energy for their activities is derived from the oxidation, ultimately of foodstuffs, but immediately of molecules attached to the living protoplasm. A necessary condition, therefore, for the life of these cells is the presence of oxygen in the surrounding medium, from which it is taken up in the molecular form. We may therefore, speak of an assimilation of oxygen; but it is still a matter of dispute whether the oxygen is built up as much in the living molecule (so-called intramolecular oxygen) to be utilized for the formation of carbon dioxide when a discharge of energy is necessary, or whether it is only taken in at the moment when the combustion of the carbon and hydrogen constitutents of the food or protoplasm is necessary for the supply of energy. However this may be, products are formed as a result of this oxidation which are of no further value to the cell and are therefore excreted, *i. e.*, turned out of the cell." (Starling.)

Dissimilation.—Living organisms are continually adjusting themselves to their immediate environment and these adjustments tend to allow the organism, whether a cell or an elephant to live and preserve its structural identity. Fundamentally this adaptation is a response to some form of stimulus from the outside unless it is assumed that living protoplasm can be the source of a stimulus for a response. However that may be, the great majority of the stimuli are external, especially in the simple forms of cell life. The power to respond to a stimulus is a fundamental property of protoplasm, but in every response energy is used which causes the protoplasm to be broken down. The first steps in this process of protoplasmic disintegration are unknown. Some of the substances thus produced represent split-off products of some of the foods, others are the products of the living protoplasm. A large number of products are thrown off from the cell as a result of its various forms of activity and the term excretion can properly be applied to them. The sum total of the processes of assimilation and dissimilation are properly described as the metabolism of the cell.

Respiration.—While the taking in of oxygen is a part of assimilation it may for the sake of emphasis be restated. In addition to food all forms of living protoplasm take in oxygen which is respiration. The structures through which the oxygen must pass whether it exists in the air or in solution in water does not change the process. Oxygen is indispensible to the life of protoplasm.

Relation of Nucleus to Cytoplasm.—In all of the discussion of the life of the cell no mention has been made of the work of the nucleus as such, nor of the work of the cytoplasm. Can they be separated and continue to live? Is there any evidence to show that the cell is a physiological unit as well as a structural unit? In attempting to answer these questions it is necessary to resort to experiments in the behavior of fragments of cells without a nucleus. When such protozoa as ameba or stentor are cut into fragments the one which contains the nucleus, or a portion of the nucleus, will regrow the lost parts in a few days, while those without a nucleus show no signs of regeneration although they may live for a couple of weeks. The non-nucleated fragments do not have the power to take in food. There seems to be a delicate relation between the nucleus and cytoplasm of each cell which permits the cell to carry on the process of assimilation and the cell must be regarded as a physiological unit, *i. e.*, both nucleus and cytoplasm are necessary in carrying on the fundamental physiological activities of a cell.

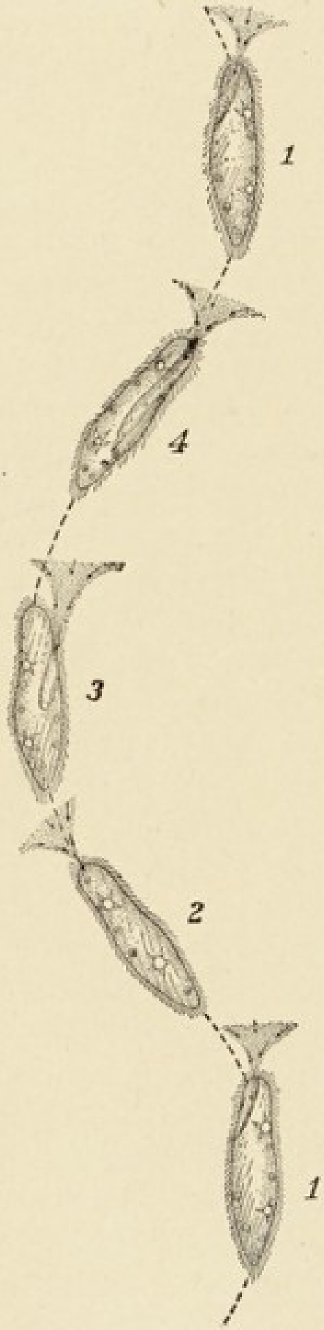
Conditions of Cell Life.—There seems to be a definite range of temperature for each living cell and beyond the extremes death usually results. In aquatic forms of life a slight increase or decrease in temperature may be fatal especially to embryonic stages of growth. The cold of fall renders the snake and frog inactive and trees cease their period of activity. In birds and mammals the body has assumed a constant temperature so that the cell activity continues during the winter, for the cells are working at a constant temperature winter and summer. In growing any of the elementary forms of life, it is necessary to know the limits of their activity and it is found that these vary with different forms.

MOVEMENT

Trial and Error.—One of the most obvious facts about animals is their power to change their relations to objects through movement. In the higher animals there are the well-known methods of locomotion in the water, on land or in the air. Trees and plants are stationary except as acted upon by the wind, etc., and remain in a definite place. They cannot change their relation to other objects. As the range of study is carried downward until plants and animals seem to merge into forms of life that have all of the fundamental vital powers equally developed, these common forms of life as well as the simplest plants are seen to have the power of locomotion more or less developed. As the simpler cells are studied to see how they move and whether there is any method in their movement, one of the fundamental questions of animal life is introduced *i. e.*, animal behavior. That there is a definite method of locomotion is recognized and it can best be described in the words of Jennings. "A certain type of behavior in higher animals has been characterized by Lloyd Morgan as the method of trial and error. The nature of such behavior is well brought to mind by an example from Morgan. His dog was required to bring a hooked walking stick through a narrow gap in a fence. The dog did not pause to consider that the stick would pass through the narrow opening only if taken by one end and pulled lengthwise. On the contrary, he simply seized the stick in the way that happened to be most convenient, near its middle, and tried to carry it through the gap in the fence in that manner. Of course, the stick would not pass, and after some effort the dog was forced to drop it. Then he seized it again at random, and made a new effort. Again the stick was stopped by the fence; again the dog dropped it, took a new hold, and tried again. After several repetitions of this performance, the dog seized the stick by the hooked end. This time it passed through the gap in the fence easily. The dog has 'tried' all possible methods of pulling the stick through the fence. Most of the attempts showed themselves to be 'error.' Then the dog tried again, until he finally succeeded. Thus he worked by the method of trial and error."

This method of reaction has been found by Lloyd Morgan, Thorndike, and others, to play a large part in the development of intelligence in higher animals. Intelligent action arises as follows: The animal works by the method of trial and error until it has come upon the proper method of performing an action. Thereafter it begins with the proper way, not performing the trials anew each time. Thus intelligent action has its basis in the method of "trial and error," but does not abide indefinitely in that method. This is the general plan of behavior among the lower organisms under the action of the stimuli which pour upon them from the surroundings. On receiving a stimulus that induces a motor reaction, they try going ahead in various directions. When the direction followed leads to a new stimulus, they try another, until one is found which does not lead to effective stimulation. This method of trial and error is especially well developed in free swimming, single-cell organisms—the flagellate and ciliate *Infusoria*—and in higher animals living under similar conditions, as in the *Rotifera*. In these creatures the structure and the method of locomotion and reaction are such as to seem cunningly devised for permitting behavior on the plan of trial and error in the simplest and yet most effective way.

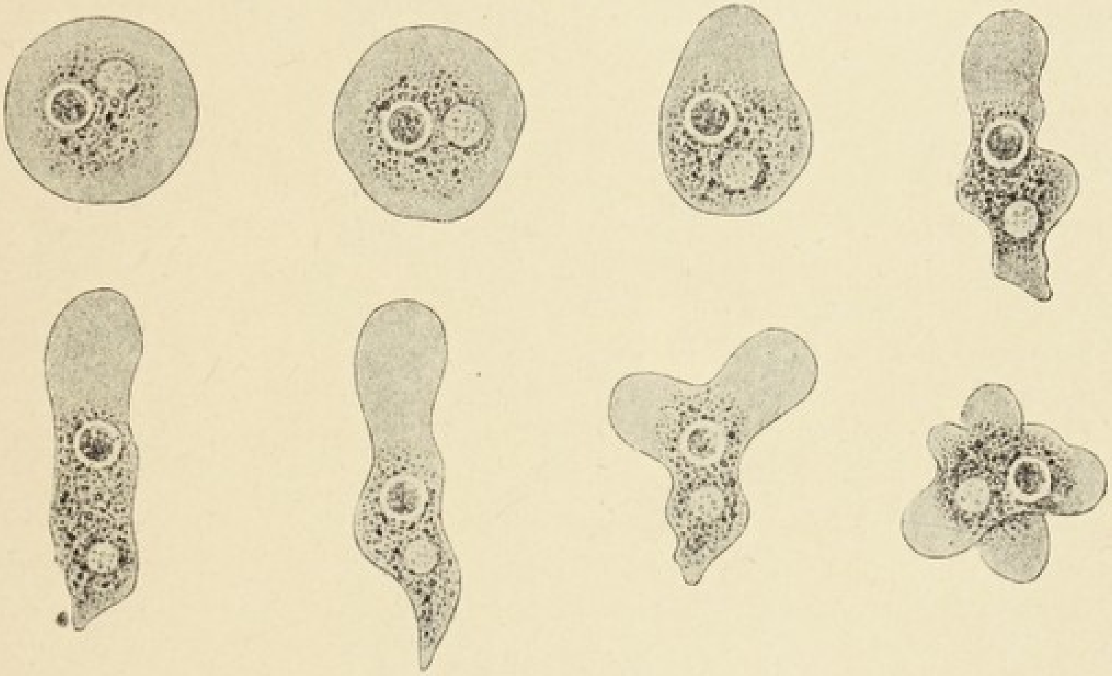
FIG. 100



Spiral path of *Paramecium*. The figures 1, 2, 3, 4, etc., show the successive position occupied. The dotted areas with small arrows show the currents of water drawn from in front. (From Jennings.)

These organisms, as they swim through the water, typically revolve on the long axis, and at the same time swerve toward one side, which is structurally marked. This side we will call X. Thus the path becomes a spiral. The organism is, therefore, even in its usual course, successively directed toward many different points in space. It has opportunity to try successively many directions though still progressing along a definite line which forms the axis of the spiral (Fig. 100). At the same time the motion of the cilia by which it swims is pulling toward the head or mouth a little of the water from a slight distance in advance. The organism is, as it were, continually taking "samples" of the water in front of it. This is easily

Fig. 101

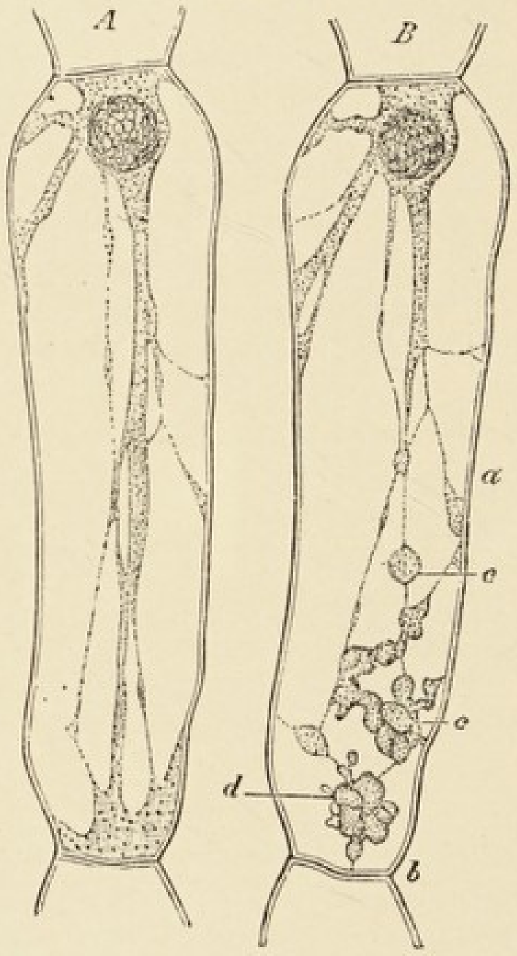


Amœba, showing successively different shapes in creeping; the hyaline exoplasm flows constantly forward; in the middle and behind lies the granular endoplasm, containing the (darker) nucleus and the (lighter) vacuole. (After Verworn.)

seen when a cloud of India ink is added to the water containing many such organisms. Thereupon the organism reacts in a very definite way. At first it usually stops or swims backward a short distance, then it swings its anterior end farther than usual toward the same side X to which it is already swerving. Thus its path is changed. After this it begins to swim forward again. The amount of backing and of swerving toward X is greater when the stimulus is more intense.

Ameboid Movement.—The peculiar streaming of the protoplasm in an ameba affords an apportunity to see how the most primitive of animals moves from place to place. The shape of ameba changes while the animal is active through the formation of pseudopodia, some of which serve primarily for locomotion, while others act more like "feelers." It is easy to see these changes taking place but difficult to determine just what is happening. Jennings concludes his study of the streaming of the protoplasm of ameba as

Fig. 102



Tradescantia—cell of a stamen hair. *A*, containing quietly streaming protoplasm; *B*, the same cell stimulated by an induced current. The protoplasm in the strands has become rounded into single globules (*c*, *d*). (From Verworn, after Kühne.)

follows: "In an advancing *Amœba* the substance flows forward on the upper surface, rolls over the anterior edge, coming in contact with the substratum, then remains quiet until the body of the ameba has passed over it. It then moves upward at the posterior end, and forward again on the upper surface, continuing in rotation as long as the ameba continues to progress. The motion of the upper surface is congruent with that of the endosarc, the two forming a single stream." Protoplasmic streaming occurs also in some plant cells.

Physiological State.—"By physiological states is meant the varying internal physiological conditions of the organism as distinguished from permanent anatomical conditions. Such different internal physiological conditions are not directly perceptible to the observer, but can be inferred from their results in the behavior of the animal." (Jennings.) In explaining the activities of protoplasm three factors should be considered: (1) The action of external agents; (2) the structure of the organism; (3) their physiological states. The first two need no explanation and the third is easily illustrated from Jennings' studies. When a quiet, extended *Stentor* is stimulated by lightly touching it with a rod, it reacts by contracting. After repeating the process a number of times, the *Stentor* no longer contracts and it may be concluded that the *Stentor* has changed. This condition of the *Stentor* when it contracts and when it does not is an illustration of the difference in the physiological state of the protoplasm.

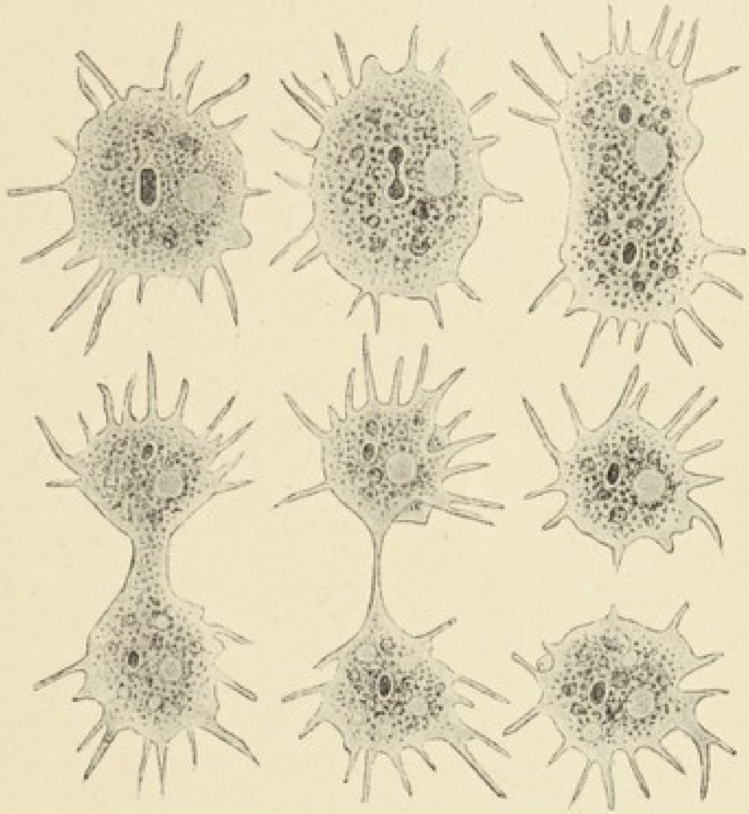
Movement Analyzed.—In order that the protoplasm of the organism may produce movement, a number of elementary properties must work together. These elementary or fundamental properties of protoplasm are: *irritability,* which is the property of protoplasm which enables it to respond to a stimulus; *conductivity,* by means of which the effect of the external stimulus is communicated to all parts of the cell; as these two properties respond, the protoplasm *contracts* which is a third property, *contractility.* These three are bound up in such a way that the animal is able to move in a definite direction; in other words, to correlate its response to a definite stimulus. The simple forms of life do not have a nervous system and yet they respond to all of the stimuli that regulate behavior in higher animals. "The reactions producted in unicellular organisms by stimuli are not the direct physical or chemical effects of the agents acting upon them, but are indirect reactions, produced through the release of certain forces already present in the organism. In this respect the reactions are comparable with those of higher animals. In the protozoa, as in the metazoa, the structure of the organism plays a large part in determining the nature of the behavior." In addition to the above fundamental protoplasmic properties there is one known as spontaneity or the power of an animal to originate movements within itself. "Spontaneous action—that is, activity and change in activity induced without external stimulation—takes place in the protozoa as in the metazoa. Both hydra and vorticella spontaneously contract at rather regular intervals even when the external conditions remain uniform." To these elementary properties of protoplasm should be added that of metabolism and reproduction. Metabolism has been discussed under assimilation and dissimilation and that must suffice in this beginning course.

REPRODUCTION

Reproduction is a universal characteristic of all forms of living matter and has reference to the way in which a new organism begins existence. It is impossible to separate growth from reproduction, because every cell which matures so as to be able to give rise to a new organism and then affords the basis for the future development into an adult organism passes through a successive series of growth changes. The term reproduction is often limited to the changes taking place in the cells while they remain attached to the parent, but in the case of the unicellular organisms there is usually no parent after reproduction but two new organisms, which are orphans in the sense that they have no living parents except as these parents exist as a part of themselves. All cells exhibit the phenomena of growth during certain periods of their life, *i. e.*, the mass of their living substance increases. The source of this growth energy is ultimately in the food supplied to the protoplasm and directly in the process of constructive metabolism. In this sense growth and reproduction are both but phases of metabolism.

Growth.—Why should cells divide and thus utilize energy that might be directed into other vital processes? As the constructive phases of metabolism continue to act, more living substance is built up than is broken down which results in the cell growing larger; but what determines when the increase in size shall stop? A casual examination of various kinds of cells quickly shows that they vary in size although there seems to be a limit beyond which none of them goes. "The explanation of growth is one of the unsolved problems of biology, and we get but little nearer in the case of protozoan organisms than in the higher forms of life. We know, indeed, that growth ceases with the elimination of the nucleus, hence, we conclude that the nucleus is a necessary factor in the process. Growth in the protozoa can be controlled in a variety of ways, and we know that certain conditions of temperature, of density, and the like, are necessary. While the explanation of the finer processes of growth is far away, the solution of the problem of cell division is almost equally remote, and no theory yet propounded satisfies the conditions as we see them in the various forms of life. Spencer's theory of volume and surface is very seductive; indeed, it may be a step toward the final solution. Briefly stated it predicates that a normal relation exists between the protoplasm and the nucleus of the cell, and if the form remains the same, this relation is disturbed by

Fig. 103

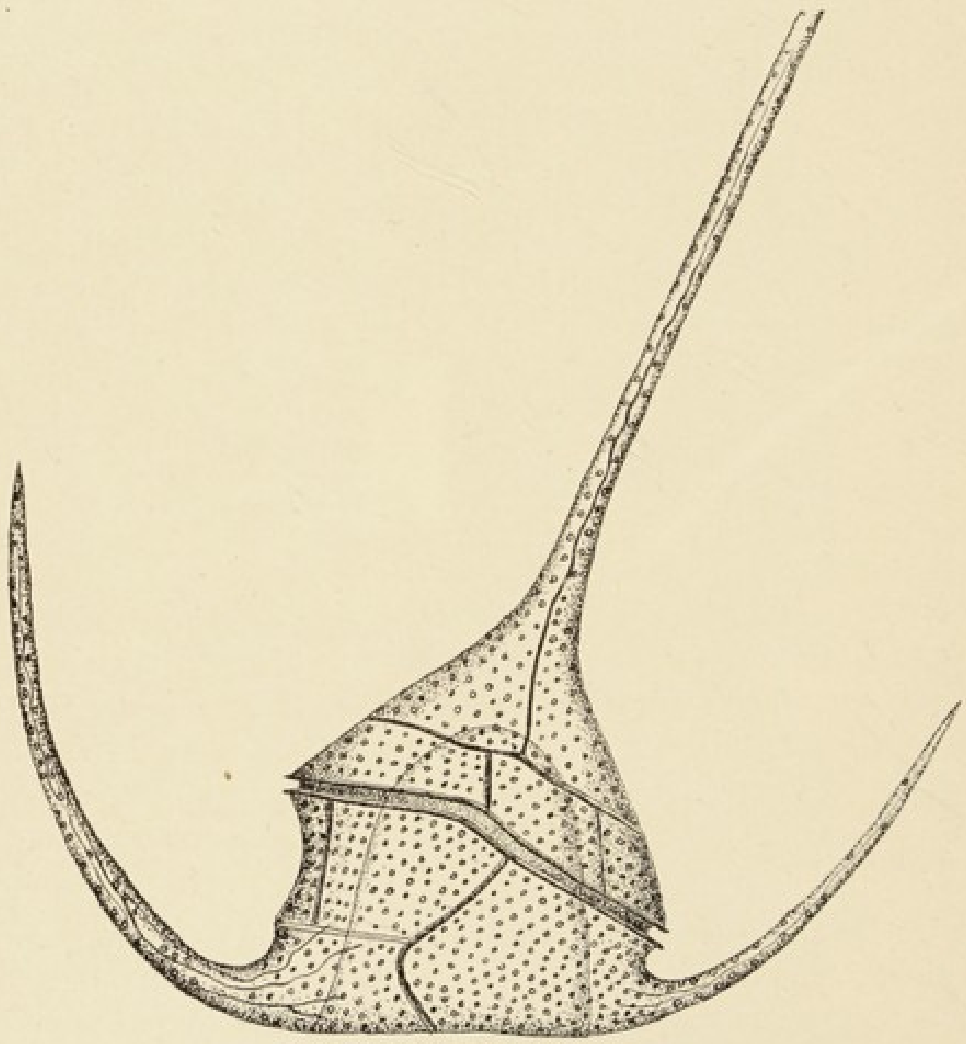


Amœba polypodia in six successive stages of division. The dark body surrounded by a clear area in the interior is the nucleus, the pale body the contractile vacuole. (From Verworn, after F. E. Schulze.)

growth, for the surface of the organism increases as the square of the diameter, while the volume increases as the cube. Hence it results that the mass increases faster than the surface which provides the means of interchange with the environment (absorption and the like). The changed ratio of surface to mass of protoplasm, according to Spencer and his followers, brings about internal changes which result in cell division. But after this theory is stated, we know nothing more about the ultimate cause of cell division than we did before." (Calkins.)

Forms of Cell-division.—Whatever may be the ultimate cause of cell-division the fact seems to be well established that the first indications of the process are seen in the nucleus. While the nucleus initiates division and the cytoplasm is subsequently constricted the details of the process are varied and the literature upon the subject has reached enormous proportions. A general outline of the essential changes may be presented under the heading of direct cell-division and indirect cell-division.

Fig. 104



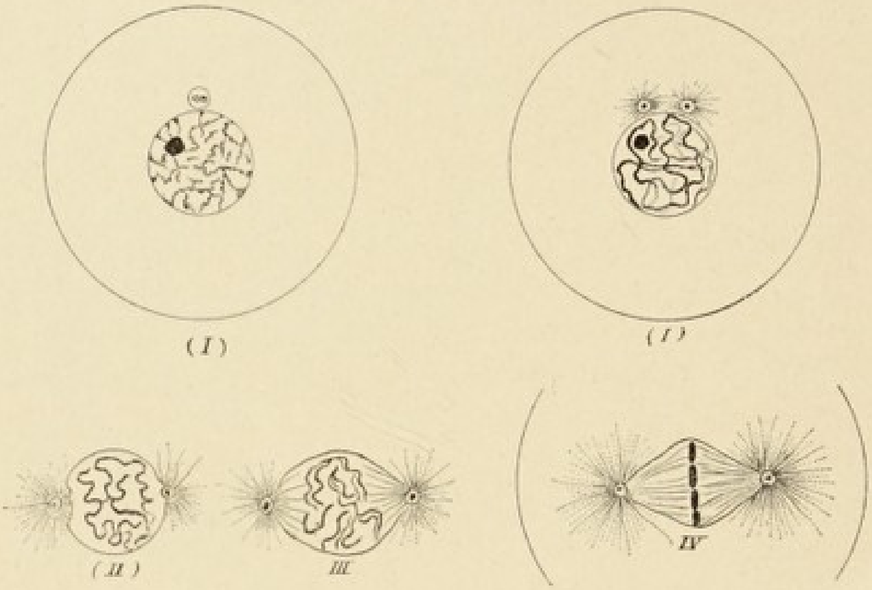
Ceratium tripos, a dinoflagellate in direct cell-division. (After Stein.)

Direct Cell-division.—The term direct cell-division or amitosis has been applied to the way in which the nucleus divides in many of the unicellular organisms. The nucleus does not undergo any elaborate preparation in this method of division. The substance of the nucleus as a whole is gradually constricted, and the part joining the two portions becomes more and more attenuated and finally breaks, with the result that there are two nuclei which again assume the shape characteristic of the non-dividing stage for the cell in question (Fig. 103). During the constriction of the nucleus the cytoplasm usually begins to divide soon after the two nuclei are formed, the cell is cut in two, each portion containing a nucleus. In this simple process of division there is no regular and uniform manner of distributing the chromatin or chromosomes, and it is doubtful if the two cells are identical in their nuclear composition. The question of amitosis has aroused more interest in the past few years than in those preceding, because it has been found to be the usual method of division in a rather wide range of animals, and while not anywhere as numerous as the direct method of division, yet numerous enough to warrant its recognition as a distinct method of reproduction in the natural method of development of certain tissues. The usual interpretation has been to regard amitosis as evidence of degeneration or occurring in cells that are on the way toward degeneration, but Child holds that typical mitosis and amitosis may appear together and apparently under typical conditions in the development of the male and female germ cells of Moniezia.

Indirect Cell-division.—In the large majority of plant and animal cells cell-division is by the so-called indirect, or mitotic, or karyokinetic method. In this method of cell-division the cytoplasm is constricted as in the direct process, but the nucleus undergoes a series of remarkable transformations. For facility in description the stages have been given well-known names, although there is no sharply defined limit to each stage, for the transformation is a continous process repeated in all of its complexity each time the cell divides. The names given the several steps are the same as stated on page 68 in describing the phenomena of maturation in the egg of the frog: (1) The prophase or preparatory stage; (2) the metaphase, during which the chromatin is separated; (3) the anaphase, which distributes the chromatin; (4) the telophase, during which the cell divides.

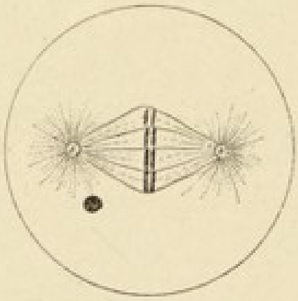
Prophase.—The first indications of approaching division are noted in certain marked changes in the nucleus. These consist in the gradual increase in the amount of chromatin and its arrangement into discrete bodies. The net-like arrangement dissappears and in its place are found deeply staining rod-like structures known as chromosomes. It is important to remember that the chromosomes come into existence through a gradual growth of certain parts of

Fig. 105



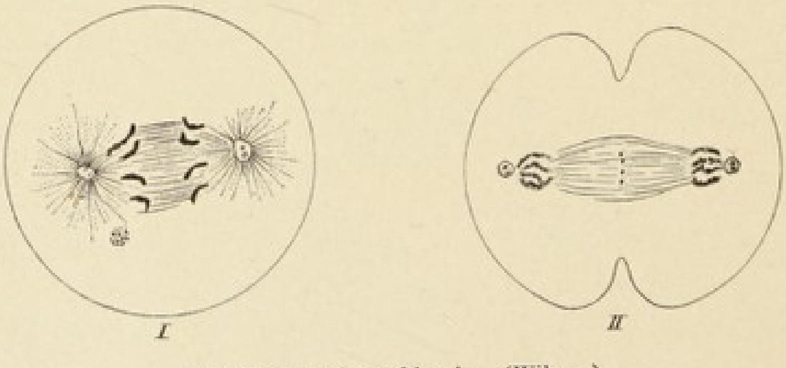
Prophases of karyokinesis. *I*, division and migration of centrosome; *II*, resolution of chromatin into well-defined thread; *III*, segmentation of same into chromosomes; *IV*, development of amphiasters; chromosomes equatorial. (Wilson.)

Fig. 106



Metaphase of karyokinesis. (Wilson.)

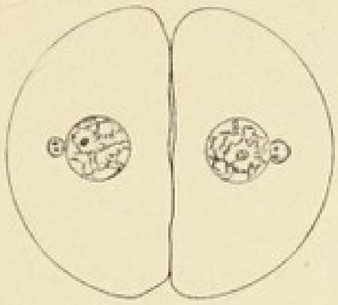
Fig. 107



Anaphases of karyokinesis. (Wilson.)

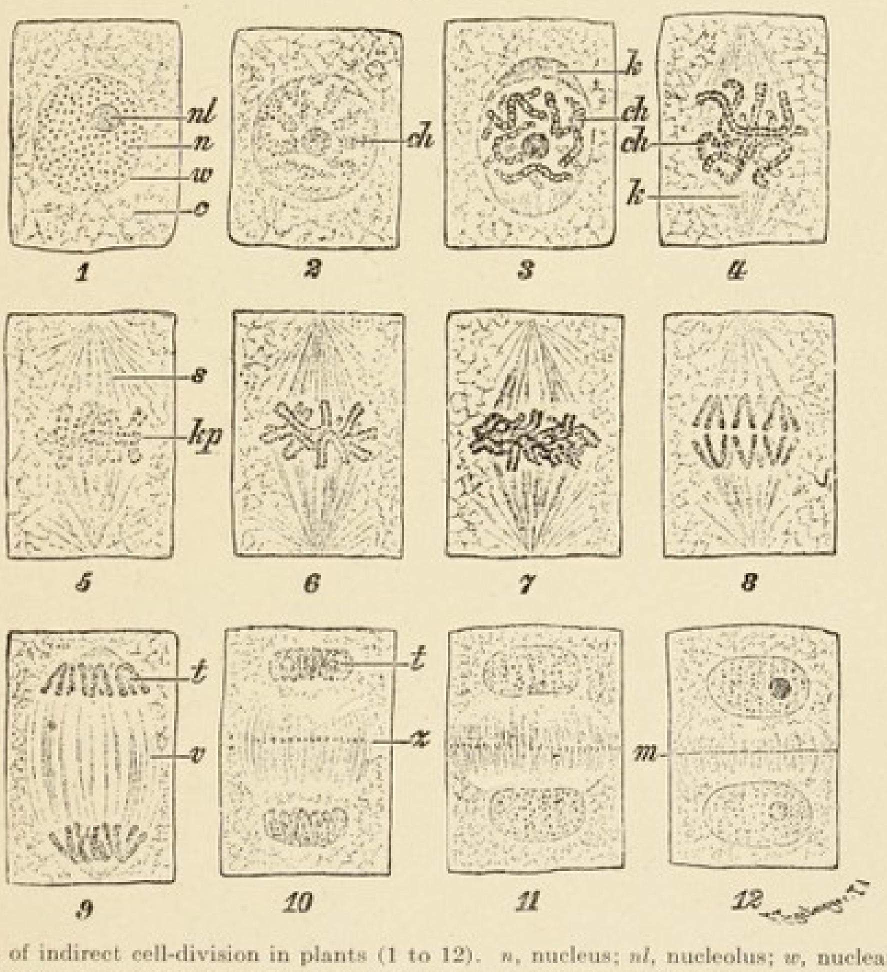
the chromatin network. The early stage in this growth when the chromatin has taken on the form of a more or less continuous thread

FIG. 108



Telophase of karyokinesis. (Wilson.)

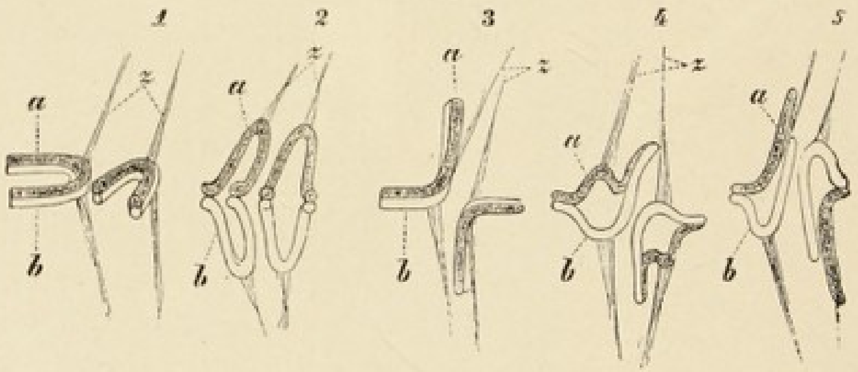
FIG. 109



Scheme of indirect cell-division in plants (1 to 12). *n*, nucleus; *nl*, nucleolus; *w*, nuclear wall; *c*, cytoplasm; *ch*, chromosomes; *t*, daughter nucleus; *v*, *z*, *m*, cell plate. (Strasburger, Noll, Schenck, and Karsten.)

is called the spireme stage. In whatever form the spireme is found it ultimately breaks up into a given number of chromosomes, *i. e.*, "every species of plant or animal has a fixed and characteristic number of chromosomes, which regularly recurs in the division of all of its cells." (Wilson.) The number of distinct chromosomes is no evidence of differentiation, for some of the protozoa have more chromosomes than man. During these changes in the chromatin and the breaking down of the nuclear membrane there is formed in the cytoplasm a structure known as the amphiaster, which consists of a spindle composed of numerous fibers and an aster at each end. In the centre of the aster is found the centrosome, which does not have a constant structure; in fact, it is absent in most plant cells during division. There was a time when great emphasis was placed upon the centrosome, with the result that too great importance was assigned to its part in cell division. The spindle fibers and astral rays for the most part are formed from the cytoplasm (Fig. 109). While the amphiaster is forming the chromosomes group themselves in the equatorial plane of one spindle. The complete mitotic figure thus consists of the chromosomes and the amphiaster.

FIG. 110



Scheme to show the separation of the daughter chromosomes from a single mother chromosome: *a*, *b*, daughter chromosomes; *z*, nuclear spindle. (Strasburger, Noll, Schenck, and Karsten.)

Metaphase.—The real division of the nucleus begins now in the splitting of the chromosomes into exactly similar halves. The initial steps in the chromosome division may take place earlier, but this does not affect the fact that there is distributed to the daughter nuclei about to form, equivalent portions of the chromatin. Just how the chromosomes are separated and moved toward each pole is a debatable question.

Anaphase.—As soon as the chromosomes have divided they are arranged into two groups, which become crowded into an irregular mass as they move toward each pole.

Telophase.—In this final stage the whole cell is divided and the chromosomes are gradually organized into a nucleus, secreting a nuclear membrane. In most animal cells the amphiaster is gradually transformed into cytoplasm. Its work has been done in bringing about the regular separation of the chromosomes. There are many additional details in this process of cell division and many variations when plant cells are considered, but the general plan outlined describes the essentials of the process.

Division Zone.—In the many unicellular organisms that divide, whether the manner of division is direct or indirect, is there a constant region in which the division occurs? Calkins has attempted to answer this question by making a series of cutting experiments on paramecium, and concludes as follows: There is strong evidence of a division zone in paramecium which lies in the centre of the cell. If the cell is cut anterior or posterior to this zone the fragment divides in the original plane into a truncated abnormal form and a normal form. The truncated form may divide again, not through the centre, but through the centre of the cell were it perfect. Cell reproduction and cell regeneration are entirely independent phenomena. In all of his cutting experiments it was noticeable that paramecium acted as a unit in which the cytoplasm and nucleus were equally important, as a small loss of either at the cut surface was enough to throw the physiological mechanism out of gear and lead to death, to asymmetrical division, or to monster formation.

Biology of Cells.—The biological study of cells affords a large number of problems, many of which have had to be omitted from the above discussion. It is important to realize that all modern studies of protoplasm assume an accurate knowledge of these general features of cell activity and cell structure. The fact that protoplasm exhibits a series of elementary vital phenomena that find various expression in higher animals and plants makes their study the real foundation for the remainder of this work. These phenomena for the sake of description are given separate names, although taken as a whole they constitute what makes matter living.

CHAPTER XI

BIOLOGY OF BACTERIA, YEAST, AND MOULDS

Laboratory Studies.—The amount of time that may be given to this section will vary with each teacher and depend to some extent upon laboratory facilities. Yeast should be nourished with Pasteur's solution with and without sugar, etc., and the results observed in a ferment saccharimeter. This may be followed by a microscopic study of the morphology of yeast. A hay infusion furnishes several kinds of common bacteria. Others should be grown on culture media and their physiology studied.

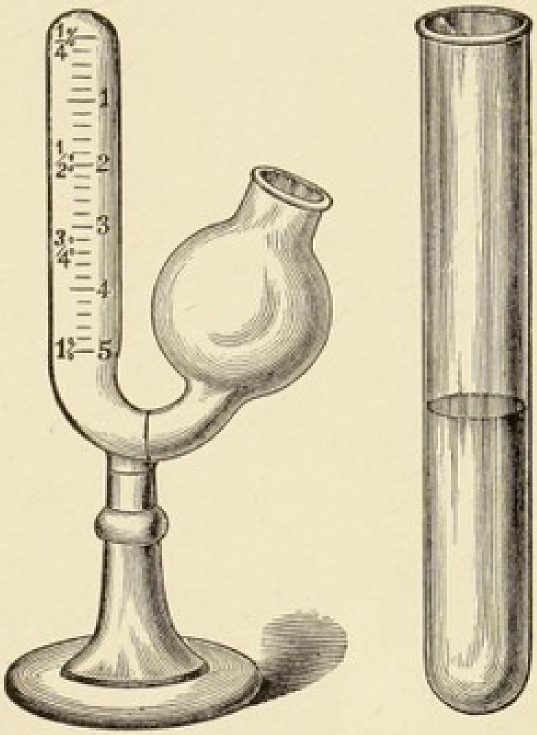
Organized Ferments.—This chapter will be limited to a general survey of the more important of the so-called organized ferments, together with some of the common moulds. Possibly the term organized ferments is one that can be dropped, although it has been in use for many years. It was applied at first to such forms of cell life as have the ferment associated with the life of the cell. It was believed for many years that these ferments could not be separated from the protoplasm which produced them and that their ferment action ceased with the death of the protoplasm. Büchner demonstrated that yeast could be ground with infusorial earth and a juice extracted which had the power to cause alcoholic fermentation. The yeast plant may be killed by alcohol, ether, or acetone and still retain its power to cause fermentation. In a similar manner the bacteria which cause lactic acid in milk can be killed so that they do not grow or divide, and yet they can form lactic acid. These experiments are difficult to perform, but are valuable as showing that the enzymes are to be classed as similar to those found in the higher animals and plants. In one sense the term organized ferments may be retained, since in nature these intracellular[1] enzymes are found acting through the living protoplasm that produces them. They are not poured out as is the saliva or the pepsin, which may be described as extracellular enzymes.

Yeast.—The word yeast is a general name for a half dozen or more distinct species of plants found growing wild and cultivated.

[1] Vernon, Intracellular Enzymes, 1908.

Because yeasts feed upon sugar the term saccharomycetes is given them. These plants are necessary in bread-making and in the man-

Fig. 111



Einhorn's saccharimeter.

ufacture of liquors. If yeast is to grow and thrive the temperature may range from 9° to 60° C. When dried it can endure a higher temperature. It thus requires a definite environment if it is to live.

Fig. 112

Saccharomyces, yeast cells. (From Verworn, after Reinke.)

Morphology of Yeast.—If a small amount of compressed yeast is mixed with water and then examined with the microscope a large number of oval and egg-shaped bodies are seen. The majority are either unicellular or have small buds attached. Sometimes a short chain of buds is noted. There is a definite cell wall composed of "yeast cellulose." The living protoplasm is granular and usually contains a number of vacuoles filled with sap. The beginning student frequently mistakes the sap vacuoles for the nucleus. Many minute glistening dots can be made out which are probably fat. No chlorophyll or starch is found in the protoplasm. The nucleus is a coarsely granular body and can be differentiated by the use of proper stains.

Reproduction of Yeast.—The usual process of reproduction is easily seen in any study of yeast in water. The method is similar to fission in protozoa, except that there is a large parent mass and a small offspring. The nucleus divides by amitosis and the bud remains attached for some time. Occasionally yeast exhibits the formation of spores by a process which results in dividing the protoplasm of the cell into two, three, or four distinct masses. When the old cell wall breaks down under proper environmental conditions each spore is capable of starting a new series of yeast plants.

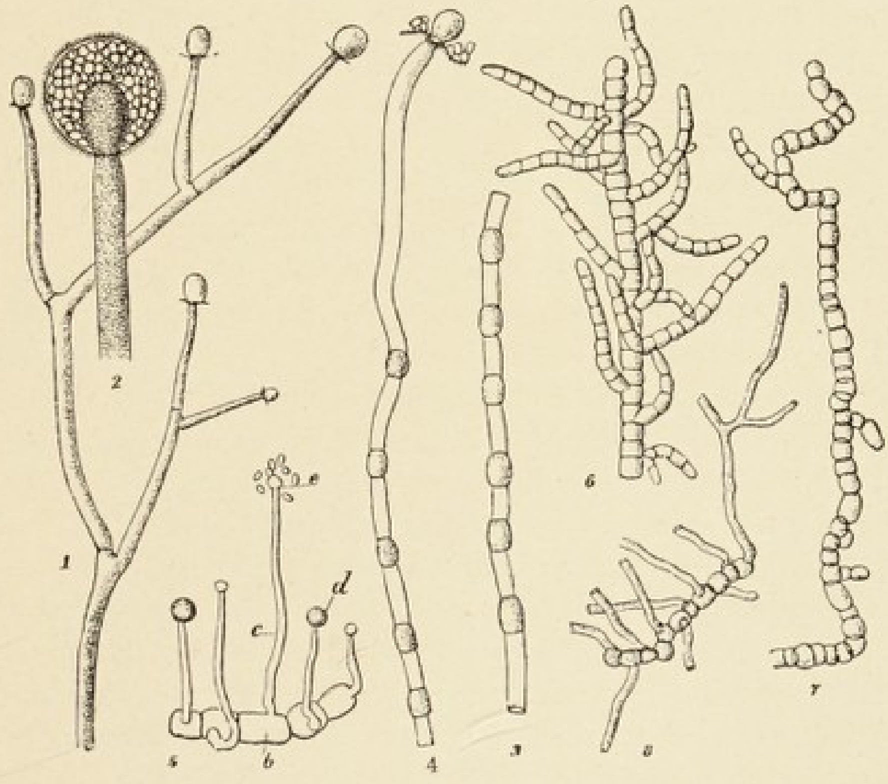
Food of Yeast.—Pasteur devised a solution which contains only mineral matter, although the nitrogen is in a more complex compound than the nitrates, which are utilized by green plants.

Water, H_2O	83.76 per cent.
Cane sugar, $C_{12}H_{22}O_{11}$	15.00 per cent.
Ammonium tartrate, $(NH_4)_2C_4H_4O_6$	1.00 per cent.
Potassium phosphate, K_3PO_4	.20 per cent.
Calcium phosphate, $Ca_3(PO_4)_2$	.02 per cent.
Magnesium sulphate, $MgSO_4$	.02 per cent.
	100.00 per cent.

The yeast is able to grow in this fluid and make more protoplasm; it must, therefore, have been able to utilize inorganic material as the whole source of its food energy. This is a physiological property that is probably lacking in the unicellular animals, although some recent researches assign a rather higher synthetic power to animals. The green plant cells are able to utilize simpler nitrogen compounds than is the yeast, so that the yeast occupies an intermediate position between animal and green plant cells in its ability to manufacture its own food out of the raw elements. It can use nitrogen in the higher forms of proteids, and in this sense approaches more closely to the animal cell. Free oxygen is as necessary to yeast as to any form of living matter.

Metabolism.—The yeast plant is able to build up its own food from the mineral substances furnished in Pasteur's solution and utilize them in the making of more yeast protoplasm. The series of changes through which foods must pass in becoming living protoplasm we must believe are similar in all forms of life. There is then in the yeast plant digestion of foods by intracellular enzymes. It is probable that there is a separate form of enzyme for the protein digestion and another for the carbohydrate. The digestion of the foods must be followed by a series of up-building stages which finally result in the food becoming protoplasm. The yeast does work in growing new cells and causing fermentation, as in bread, where the temperature is raised by the fermentation process. This requires energy and is an outgo from the cell. To this may be added carbon dioxide and nitrogenous wastes, although these wastes are masked in part by the presence of other substances in the culture solution.

Fig. 113



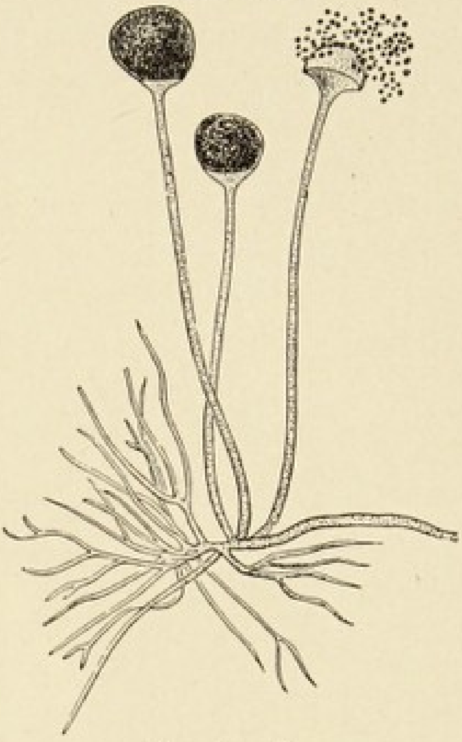
Development of lower fungi. 1, branched filament carrying spores; 2, cross-section of spore highly magnified; 3 and 4, spore building; 5, developing and bursting spores; 6 and 7, branching; 8, sprouting spores. (After Tazel.)

Fungi.—The yeast belongs to the general class of plants known as Fungi. The general habitat of this group is well expressed by Underwood as follows: "Whether we are aware of their existence or not, there are in the world about us a vast array of more or less inconspicuous organisms that are known to botanists under the name of fungi. These differ among themselves in size and structure far more widely than do a violet and an oak, and many of them at first sight would seem to bear so little resemblance to one another as to possess no real relationship. Many of them are known more or less popularly under common names, such as moulds, mildews, mushrooms, toadstools, puff-balls, rusts, smuts, leaf spots, and blights, each popular name indicating a more or less indefinite group of plants more or less closely related to one another. They grow in every conceivable place where organic matter can be found which will serve as their food, and a moderate degree of heat and moisture are present to furnish the necessary conditions of growth. Decaying fruit or vegetables, oily bones, old musty shoes, wet paper, the dead stem of herbaceous plants and woody plants, the dead and dying branches of trees, standing stumps and tree trunks and fallen logs all furnish the matrix in which fungi of various sorts, a few conspicuous, many more inconspicuous, thrive and multiply. With all their differences fungi agree in two characters: (1) No chlorophyll. (2) They reproduce by spores. In the many different substances enumerated above all are the product of some form of organic activity. This permits the habitat of fungi to be subdivided into (1) those that live upon dead organic matter and are called saprophytes and (2) those that subsist upon living organisms and are known as parasites."

Bread Mould.—This is a common form of one of the simple moulds that grow in abundance in our homes upon bread, fruit, and other suitable substances. It consists of a tangled mass of thread-like structures which is the main working body of the plant. The name mycelium is given to the interwoven mass which may become quite compact in older growths. The individual threads are called hyphæ. Some of the hyphæ send out special threads that penetrate the nutrient material, which are known as rhizoids. The bread mould derives its nourishment directly from the nutrient substances upon and in which it is growing. We may believe that the foods found in the bread are utilized through the production of certain enzymes by the hyphæ. The reason for believing that this is the method is because *Aspergillus niger*, a mould, has the reputation of forming a large number of enzymes; and *Bencillium camemberti* (the chief organic agent in ripening Camembert cheese), according to Dox, produces the following enzymes: erepsin, dulclase, aminase, lipase, emulsin, amylase, inulase, raffinase, invertase, maitase, and lactase.

The formation of the mycelium takes place by the asexual or vegetative method of reproduction. After a time a number of upright stalks are produced from the mycelium and are called sporangiospores (sporangia bearers). The tip of each upright branch produces a globular sporangium which is full of spores. The walls of the sporangia burst and the dust (spores) is scattered by air currents. This is the usual method of reproduction, although a sexual form of reproduction is rather common.

Fig. 114



Bread mould.

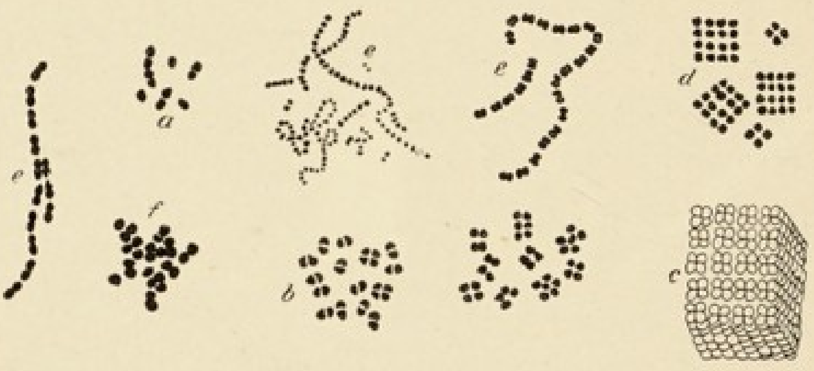
Water Mould.—There is one very common water mould that lives upon dead insects, fish, and other animals. This mould has the interesting habit of thriving either on a dead fish or one that is alive, readily assuming the saprophytic or the parasitic habit. At times it becomes a serious pest in fish culture. A culture of water mould (saprolegnia) is usually secured by simply dropping a dead fly found on the floor or window sill into a dish of water. There is soon formed a whitish mass of hyphæ growing out in all directions from the insect. The hyphæ on the body of the insect digest such parts as may serve as food, and it is in this way that they are effective agents in destroying dead animals in the water. The water mould reproduces by the asexual and sexual methods. The water and bread moulds serve to illustrate a type of plant life that has its food already made; they are plants related to certain green plants and they differ from them chiefly in the absence of chlorophyll. This suggests that the habit of utilizing ready-made food is really an acquired habit. More or less closely related to these common moulds are the mildews, rusts, and many others less well known.

BACTERIA

Relationships.—There has been much concern in the past as to the general relation of the bacteria and whether they should be grouped with the plants or animals. Their exact relationship is a question in some dispute. They are related more closely to a group of algæ known as the blue-green algæ than to any other definite group of plants or animals. Their method of locomotion and in some instances the manner of spore formation reveals well-recognized protozoan traits. In the main they are best regarded as plants because of their power to live usually without already prepared protein food and because of their method of reproduction. In their general physiology they are more like fungus plants and so are classed under the fungus term (mycetes) as *Schizomycetes*.

Morphology.—Bacteria appear in three general shapes—the straight rod (bacillus), the bent rod (spirillum), and the sphere (coccus or micrococcus). "There are spherical forms of wide difference in

Fig. 115

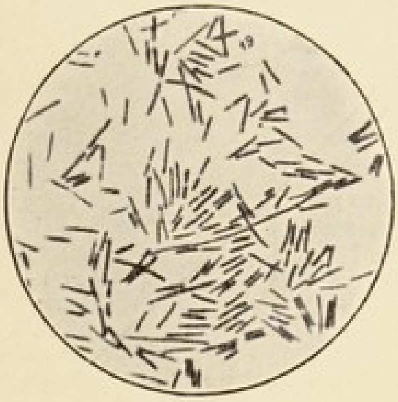


Varieties of spherical forms. *a*, tendency to lancet-shape; *b*, tendency to coffee-bean shape; *c*, in packets; *d*, in tetrads; *e*, in chains; *f*, in irregular masses. ×1000 diameters. (After Flügge.)

sphericity, rod forms with great variation in length and diameter, and spiral forms having from a fraction of one spiral to many spirals. Furthermore, spherical forms may become piled upon one another so that colonies result, and rods may be joined in such a way as to construct filaments. Within these groups many species of bacteria are known. One high authority, Migula, considers that there are 1272 distinct species of bacteria, most of which belong to the bacillus type." (Bergen and Caldwel.) A single species may exhibit considerable variation when studied under different conditions of growth, appearing first in one shape then in another. Such changes are, however, never permanent, but it is readily seen that the mere morphology of bacteria is not a safe method upon which to determine species.

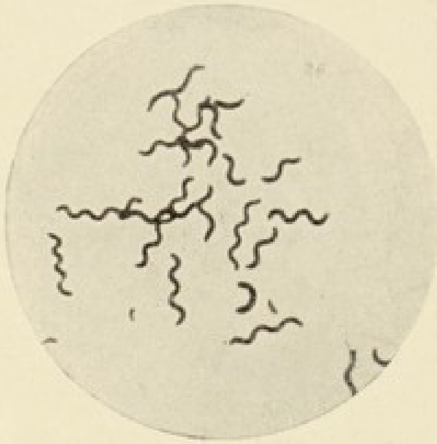
Size.—"The bacteria were formerly spoken of as the smallest of living things, but since the recognition of ultramicroscopic organisms it is necessary to be more specific in characterizing their dimensions. The unit of measurement in microscopy is the micron (μ) or micro-millimeter. This is 0.001 of a millimeter or approximately $\frac{1}{25000}$ of an inch. Applying this unit to bacteria we find that the micrococci and the short diameter of the bacilli and spirilla average about 1 μ.

Fig. 116



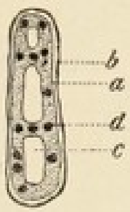
Long slender bacilli. × 1000 diameters. (After Park.)

Fig. 117



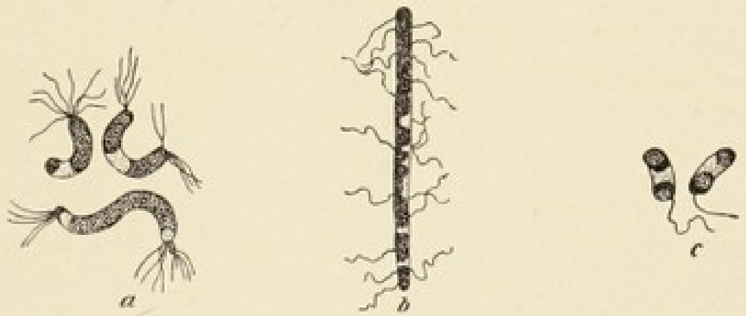
Very large spirilla. (After Park.)

Fig. 118



Structure of bacterial cells. (After Bütschli.)

Fig. 119



a, spirillum undula; *b*, bacillus solmsii; *c*, vibrio choleræ. The flagella are well shown. (After A. Fischer.)

The micrococci vary in diameter from a small fraction of a micron to three or four microns in diameter. The bacilli are sometimes very small, as the influenza bacterium, with a width of 0.2 μ and a length of 0.5 μ, and sometimes very large, as for example the Bact. anthracis, with a width of 0.2 μ and a length of 5.2 μ. The spirilla average about 1 μ in diameter, but may be as long as 30 or 40 μ." (Frost.)

Structure.—Bacteria are extremely simple plants and are regarded by many as the simplest known living things. The cell wall may be slimy or gelatinous, and is not like the cell wall of the higher plants, which is composed of cellulose. Their diminutive size prevents one from learning very much about the cytoplasm. There is no distinct nucleus. The essential part of this organ is believed to be represented by certain granules. From the cell wall in some species a number of cilia or flagella project which are used in locomotion.

Fig. 120

a b c

a, spiral forms with a flagellum at only one end; *b*, bacillus of typhoid fever with flagella given off from all sides; *c*, large spirals from stagnant water with wisps of flagella at their ends (*Spirillum undula*). (After Abbott.)

Motility.—The organs of locomotion are used by the bacteria in moving from place to place. "Some dart with great rapidity, others move slowly; some move in straight lines, others wobble, but any particular character is quite constant, and many of the bacteria may be recognized by their characteristic movements. Their rate of movement varies greatly with the species. As they are viewed under the microscope their motion seems very rapid. The typhoid bacillus has been estimated to travel 2000 times its own length in an hour, while the cholera spirillum may go 45 times as fast. It is probable that their rate is little greater than that of a trotting horse."

Reproduction.—"This is accomplished by means of binary fission. When a bacterium has reached maturity, fission begins. This change in the cell is not customarily regarded as preceded by any series of changes comparable to karyokinesis (mitosis) in the higher cells, since no nucleus in the ordinary sense has been demonstrated in the bacterial cell. Division begins by an invagination of the protoplasm in the middle of the cell, which proceeds until the cell protoplasm is completely separated. The cell wall then grows in and finally splits, forming the two ends of the new cells. These new cell walls are formed at right angles with the long axis of the cell in the case of the bacilli and spirilla, except in rare instances. In the case of micrococci the throwing of the cell wall across one diameter is quite as economical as any other and may therefore proceed in any direction. Migula makes a considerable point of the fact that bacilli and spirilla elongate before division and micrococci divide before they elongate, and this is the criterion which he would use to separate these two-form types. A generation among the bacteria is from one division of the cell to another. This is sometimes very short, in fact, only twenty or thirty minutes. Many of the bacteria after a half hour's time have grown from newly formed cells to maturity and are ready to divide again. This makes it possible for bacteria to multiply with great rapidity, and if we know the length of the generation in a particular bacterium it is easy enough to estimate the rate of multiplication, at least theoretically. It is of course quite impossible for the bacteria to maintain their theoretical rate of growth for any length of time, but practically, they grow with enormous rapidity, as is shown in cultures and in the changes which they bring about in nature, such as the production of fermentation and the generation of toxins." (Frost.)

Under certain conditions a considerable number of bacteria form spores. The protoplasm is broken up into a number of bodies within the cell, which are then called endospores. Their chief value seems to be to enable the bacteria to undergo unusual and unfavorable conditions. In this condition, bacteria possess remarkable powers of resistance.

Zoöglea.—The mother of vinegar is a good illustration of this condition of bacteria. The cells secrete a mucilaginous substance that causes them to cohere in great numbers. In some instances this condition represents a stage in the life history, while in the vinegar it is induced by the formation of a certain amount of acetic acid.

Metabolism.—Jensen divided bacteria into three groups according to their method of securing food. (1) Bacteria which are like the green plants in requiring neither organic carbon nor organic nitrogen. These are the so-called autotrophic bacteria, which possess the remarkable property of being able to build up both carbohydrates and protein out of carbon dioxide and inorganic salts. (2) Bacteria which need organic carbon compounds, but can dispense with organic nitrogen. These organisms can synthesize protein out of carbohydrates or organic acids and ammonia, nitrogen or nitrates. (3) Bacteria which are like the animals in requiring both organic carbon and organic nitrogen compounds. This group cannot bring about either protein or carbohydrate synthesis out of inorganic substances. The metabolism of bacteria may then show all of the phases already described for green plant cells and for animal cells as well as certain intermediate stages. The food is absorbed directly through the cell wall and is as varied as is their habitat. There seems to be no form of organic substance living or dead that may not serve as a source of food supply for bacteria, so that the enumeration of their foods becomes practically impossible. It would be very strange if the character of metabolism which is so fundamental in living things should be essentially different in bacteria; it probably is not, and so the usual steps in assimilation and dissimilation may be assumed to take place in bacteria. During this process enzymes are utilized and toxins produced.

Enzymes and Toxins.—"Among the most interesting and least understood products of microbial action are the enzymes and the toxins. These two groups are related in many respects. Toxins and enzymes are formed by the cells in such small quantities that they would never have been discovered by ordinary chemical means were it not for the unusual effects which they produce, the enzyme acting upon food substance and the toxins acting physiologically upon organisms. Toxins and enzymes are chemically unknown." (Hahn.)

Zoötoxia of the rattlesnake is the best known animal toxin, while phytotoxins in plants are more common. Toxins and enzymes are both very sensitive to heat, light, and certain chemicals. Both of these bodies must be defined in terms of what they do.

Fermentation.—The organized ferments all employ the same general method to effect changes in the substances upon which they act. The change due to these minute plants is very great and yet it can all be reduced to a process of fermentation. In the ordinary processes of fermentation the chemical compound is simplified. This is easily understood from the following:

Sugar.	Yeast enzyme.				Alcohol.		Carbon dioxide.
$C_6H_{12}O_6$	?	?	?	=	$2C_2H_6O$	+	$2CO_2$

Alcohol.		Oxygen.		Acetic bacteria enzyme.				Acetic acid.		Water.
C_2H_6O	+	O_2	=	?	?	?	=	$C_2H_4O_2$	+	H_2O

In this transformation through the action of the yeast enzyme and acetic bacteria enzyme the sugar molecule has become much simpler and the ultimate result is a substance entirely different from sugar—namely, vinegar. The changes are chemical in their nature. It is difficult to make any classification of ferments that is not open to criticism. There are the intracellular and extracellular enzymes that act upon the carbohydrates, proteins, and fats; these with the oxidizing and reducing enzymes may serve, however, to give a working classification.

Chemical Composition of Living Matter.—No one has been able to write the chemical formula for living matter, and after all these years of investigation but little is really known about the chemistry of living matter. One of the reasons for this lack of chemical knowledge is that as soon as a chemical analysis is applied the living protoplasm becomes dead and the chemistry of dead protoplasm is quite different from that of living. An analysis of dead protoplasm shows the presence usually of carbon, nitrogen, sulphur, oxygen, phosphorus, chlorine, potassium, sodium, magnesium, calcium, and iron. In addition to these elements there may be found others, especially silicon, iodine, fluorine, bromine, aluminum, manganese, and copper. The amount of these elements, even those that are essential to life, found in an organism bears no relation to their abundance in nature. The following summarized account of the most important elements from Starling shows their relations in nature: Carbon forms the greater part by weight of the solid constituents of living protoplasm. In the inorganic world practically all of the carbon occurs in a completely oxidized form, namely, carbon dioxide. A small amount, 4 parts in 10,000, is present in the atmosphere, while vast quantities are buried in the crust of the earth as carbonates. Practically all of the carbon in organic tissues is derived from the minute proportions of carbon dioxide present in the atmosphere. This is combined through the work of the chlorophyll into carbon compounds that can furnish energy to living matter. Hydrogen exists almost exclusively in the form of water. In this form it is taken up by plants and animals, with the exception of a small amount absorbed in the form of ammonia. Oxygen is the only element which, in all the higher organisms, at any rate, is taken up in the free state. It forms one-fifth of the atmosphere and, as the oxides of the various metals, a considerable fraction of the earth's crust; it takes a position apart from the other foodstuffs in that its presence is the essential condition for the utilization of their potential energy. Nitrogen constitutes four-fifths of the surrounding atmosphere, and can be utilized by most plants only in the form of ammonia, nitrites, or nitrates. To animals these compounds are useless, and the only source of nitrogen for this class is protein. Sulphur is found in all soils in the form of sulphates, in which form it can be taken up by plants. Iron, although forming but a minute proportion of the material basis of living organisms, is, nevertheless, indispensable for the maintenance of life. Phosphorus is absorbed by the plant as phosphates.

Nitrogen Compounds.—As just stated nitrogen in an uncombined state cannot be used as food energy by most plants. It is obvious that the amount of ammonia, nitrites, and nitrates would soon become exhausted unless there were some way of supplying more of the nitrogen compounds. Many of the soil bacteria live as saprophytes and carry on the important work of combining the free nitrogen into a form that can be used by other organisms. The several nitrogen combinations are effected through the agency of several kinds of bacteria. There are also bacteria which live in the roots of certain plants, like clover, beans, and peas, which are able to utilize the nitrogen of the air. All of the higher forms of plants and all of the animals are dependent upon microscopic bacteria for their nitrogen.

The Fate of Dead Organisms.—Ultimately all forms of life die, and yet the surface of the earth is not cumbered with them as would be the case if they remained intact after death. The group of organisms included under the heading ferment organisms, particularly the saprophytes, begin to tear down the substance of these dead bodies, and this continues through a longer or shorter time until there exist a number of free chemical elements in the place of the organism. The substance of the dead organism has been returned to nature and the chemical elements have been released and set free. None of them has been destroyed, and all of them are available to be used by some form of life. It is thus seen that the elements that enter into the living protoplasm pass through a fairly regular cycle. No one can tell how many times the oxygen that we are breathing has been a part of other living things nor for how long a time. All that we know is that it is useful to us. It does not matter how often nor how long an element is used so far as its usefulness to future living things is concerned, provided it is properly combined so that the plant or the animal protoplasm of a thousand years hence can utilize it. We may feel then that there will always be plenty of the necessary chemical elements to support life, because living matter does not destroy them and cannot exhaust them, but simply holds them in the living relation for a longer or shorter period.

Spontaneous Generation.—In Virgil's Georgics, book IV, we read that the shepherd Aristaeus lost all of his bees through disease and famine and regained them in the following manner: "Cyrene kindly bespoke her trembling son, ordering him to make humble, tender offering. Without delay he instantly executes the order of his mother; repairs to the temple; raises the altars as directed; leads up four chosen bulls of surpassing form, and as many heifers whose necks were untouched by the yoke. Thereafter when the ninth morning had ushered in her rising beams, he offers the funeral rites to Orpheus, and revisits the grove. But here they behold a sudden prodigy, and wondrous to relate, bees through all the belly hum amidst the putrid bowels of the cattle; pour forth from the fermenting juices from the burst sides, and in immense clouds roll along; then swarm together on the top of a tree, and hang down in a cluster from the bending boughs." (Lines 548 to 566.)

The following from Schafer, in 1912, shows something of how the problem has shifted since the time Virgil wrote: "So far from expecting a sudden leap from an inorganic, or at least an unorganized into an organic and organized condition, from an entirely inanimate substance to a completely animate state of being, should we not rather expect a gradual procession of changes from inorganic to organic matter through stages of gradually increasing complexity until material which can be termed living is attained? And in place of looking for the production of fully formed organisms in hermetically sealed flasks, should we rather not search nature herself, under natural conditions, for evidence of the existence, either in the past or in the present, of transitional forms between the living and non-living? We may be certain that if life is being produced from non-living substance it must be life of a far simpler character than any that has yet been observed in material which we shall be uncertain whether to call animate or inanimate. Setting aside, as devoid of scientific foundation, the idea of immediate supernatural intervention in the first production of life, we are not only justified in believing but compelled to believe that living matter must have owed its origin to causes similar in character to those which have been instrumental in producing all forms of matter in the universe; in other words, to a process of gradual evolution. If living matter has been evolved from lifeless matter in the past, we are justified in accepting the conclusion that its evolution is possible in the present and in the future."

Between these two extremes there have existed many views as to the origin of life. No one is able to prove as yet that life can come into existence other than through the influence of preëxisting life. Where life first began or under what conditions is unknown. The great work of Spallanzani, Pasteur, Tyndall, and others has proved effectually that all of the differentiated forms of life are descendants of similar differentiated forms of life. The student of biology can test the new theories that are bound to be brought forward from time to time by utilizing what has already been developed in this course, and is summarized in the following.

The Nature of Life.—In considering this topic it is not necessary to make one set of statements for animal protoplasm and another for plant protoplasm. The manner of living is fundamentally the same. True, the plant cell, at least the green plant, seems to possess the additional property of making its own food; but in the use of that food and the essential facts of reproduction, and the still more elementary properties of protoplasm, irritability, conductivity, etc., the two are in close agreement. Nor is one able to separate them on the basis of their chemical composition; in short, they are in the last analysis the same. No one has been able to write an acceptable definition of living protoplasm. No one has been able to write the chemical formula for living protoplasm, although physically it acts like a colloidal substance. It continues on the earth in a multitude of distinct species ever passing from the living to the living. In the higher forms of life there is a continual series of changes in which certain cells are dying and new ones taking their place, and their death does not affect the vitality of the whole body. A French worker has been able to keep the white corpuscles of the frog alive for a year apart from the body of the frog. It is a mistake to assume that because an organism is dead that all of its cells are dead. Just what it is that makes the difference between a living body and a corpse cannot be expressed, although the individual cells may continue to live for some time. The heart of a turtle can be taken from the turtle and the turtle dies, but the heart can be made to beat for several days afterward. The life of the cell is then in a sense distinct from that of the complex organism. This is particularly true in the case of ova and sperm cells, and it has recently been shown that certain hydroids and sponges can be cut into fine pieces and yet retain the power of growing into adult sponges and hydroids (Fig. 82). Even a consideration of death does not help much in understanding the nature of life. Possibly future researches will help to solve the riddle. The supposed new creatives of life must be judged in terms of the sum of the vital processes before it can be claimed that they are living, and these are (1) the presence of certain definite chemicals; (2) growth and differentiation; (3) reproduction; (4) metabolism; (5) irritability, conductivity, etc.; (6) production of one or more ferments.

CHAPTER XII

CLASSIFICATION — THE "WORMS" AND ARTHROPODS

Laboratory Studies.—Practical work in classification can be done by taking several species of frogs, sparrows, flies, etc., and have each student work out carefully the distinctions. From the remaining groups of animals any number of types may be selected. It is expected that the earthworm and either the crayfish or some insect will be taken up. The external features of the fish are also valuable.

CLASSIFICATION

There are more than 47,000 known members of the true vertebrates, and when to this is added the more than 360,000 insects, the star fishes, the molluscs, and the many unicellular forms there is a multiplicity of animals that is truly confusing. The earliest students of zoölogy were perplexed by the confusion of numbers and attempted to work out schemes of classification. Some of these were shrewd guesses while others were errors, because men did not understand the fundamental organization of the great groups. When biologists accepted the cell theory and biogenesis a working plan for classification was furnished, for the first shows that all forms of life have the cell as their unit of structures and the second holds that there is a genetic relationship between all animals. Biogenesis thus becomes an important working plan in all modern attempts to classify organisms, whether it be in their arrangement into the great groups or their specific designation. Scientists are in agreement as to the limits of the great groups or phyla of the animal kingdom, but when an attempt is made to arrange these phyla in a definite sequence a difference of opinion often arises.

Each phylum is variously subdivided according to the number of animals and the definiteness of their structural differentiation. Each phylum includes a number of animals that have the group characters. This is easily illustrated in the protozoa. They are minute, mostly microscopic, aquatic, unicellular animals that reproduce by fission. Each animal to be classed in the protozoan phylum must have these common characters. The next problem is to arrange the hundreds of protozoa into what are termed classes. This is done by taking certain characters that have become specialized, as the presence of cilia in *Paramecium*, and the class *Infusoria* is formed. The class *Infusoria* is subdivided on the basis of the permanency of the cilia into two orders: *Ciliata*, which are *Infusoria* that are provided with cilia throughout life, and *Tentaculifera*, which are *Infusoria* that possess cilia in the young condition and tentacles in the adult. The order *Ciliata* may include several species. A species is usually defined as a number of animals that resemble one another so closely that to know one is to know all. The several individuals which constitute a species are given a specific name. Both generic and specific names are of Latin form and either Greek or Latin origin. This enables the zoölogists of all nations to speak the same language when referring to animals. There is thus the genus *Paramecium* and the species *caudatum*, so that when this particular animal is mentioned it is called *Paramecium caudatum*.

The plan by which plants and animals are given a definite place in a consistent scheme of classification was worked out by Linnaeus, the great Swedish zoölogist (1707 to 1778). His plan was to use two words which should show their general relations and individual differences, as already shown for *paramecium*, and for the sake of clearness it may be further illustrated as follows: The cat-like animals were given the generic name of *Felis;* and all that is necessary in naming the several cat-like animals is to add to *Felis* a specific name, as *domesticus* for the common cat or *Felis canadensis* for the Canada lynx. In a similar way the dog-like animals were united under the genus *Canis*, and so there is *Canis lupus*, the wolf; *Canis vulpes*, the fox; or *Canis familiaris*, the common dog.

Every-day observation shows, however, that there is more than one kind of dog, and the species *Canis familiaris* is broken up into varieties. Many difficulties beset the systematist because no two animals are identical, and we have often found even the most important characters of the species modified, so that today one expects a certain range of variation in a species. The result is that species may overlap or pass into one another, and the expert himself is puzzled in classifying some animals.

The multiplicity of species makes it impossible for the average student of zoölogy to understand more than the principles used in classification. The following classification of some of the parasitic protozoa will serve to illustrate how complicated the study becomes:

- Protozoa
  - Rhizopoda
    - *Amœba*
      - *Amœba dysenteriæ*
      - *Amœba coli*
      - *Amœba meleagridis*
      - *Amœba buccalis*
  - Flagellata
    - *Spirochæta*
      - *Spirochæta obermeieri*
      - *Spirochæta duttoni*
      - *Spirochæta vincenti*
      - *Spirochæta pallidula*
      - *Spirochæta theileri*
      - *Spirochæta gallinarum*
    - *Trypanosoma*
      - *Trypanosoma gambiense*
      - *Trypanosoma cruzi*
      - *Trypanosoma brucei*
      - *Trypanosoma evansi*
      - *Trypanosoma equinum*
      - *Trypanosoma dimorphon*
      - *Trypanosoma lewisi*
      - *Trypanosoma equiperdum*
    - Trypanoplasma, Cercomonas, Monas, etc.
  - Sporozoa
    - Hæmosporidia
      - Plasmodium
        - *Plasmodium vivax*
        - *Plasmodium malaria*
        - *Plasmodium falciparum*
      - Proteosoma
      - Hæmoproteus
      - Hepatozoön, etc.
  - Infusoria

Animal Kingdom.—The following general plan of classifying the animal kingdom is taken from Parker and Haswell, and serves to show how animals are grouped, but does not determine the exact relation of even the great phyla.

I. Phylum Protozoa, 8000[1] species living.
 Classes 1. Rhizopoda: ameba.
  2. Mycetozoa.
  3. Mastigophora: spirochetes, trypanosomes.
  4. Sporozoa: gregarines, all parasitic.
  5. Infusoria: paramecium.

II. Phylum Porifera, 2500 species.
 Class Porifera: sponges.

III. Phylum Cœlenterata, 4500 species.
 Classes 1. Hydrozoa: hydra, sea-anemone, jelly-fish.
  2. Scyphozoa: jelly-fish.
  3. Actinozoa: corals.
  4. Ctenophora.

IV. Phylum Platyhelminthes: 5000 species.
 Classes 1. Tuberllaria: flatworms.
  2. Trematoda: liver fluke.
  3. Cestoda: tapeworms.

[1] The estimate of the number of species in each phylum is by H. S. Pratt.

V. Phylum Nemathelminthes, 1500 species.
  Classes 1. Nematoda: ascaria, trichina, unchinaria.
  2. Acanthocephala: hook-headed worms, echinorhynchus.
  3. Chætognatha.

VI. Phylum Trochelminthes, 500 species.
  Classes 1. Rotifera.
  2. Dinophilea.
  3. Gastrotricha.

VII. Phylum Molluscoida, 1700 species.
  Classes 1. Polyzoa.
  2. Phoronida.
  3. Brachiopoda.

VIII. Phylum Echinodermata, 4000 species.
  Classes 1. Asteroidea: star-fish.
  2. Ophiuroidea: brittle stars.
  3. Echinoidea: sea-urchins.
  4. Holuthuroidea: sea-cucumbers.
  5. Crinoidea: crinoids.

IX. Phylum Annulata, 4000 species.
  Classes 1. Chætopoda: earthworms.
  2. Gephyrea.
  3. Hirudinea: leeches.

X. Phylum Arthropoda, 394,000 species.
  Classes 1. Crustacea: crabs, lobsters, etc.
  2. Onychophora.
  3. Myriapoda: centipeds.
  4. Insecta.
    Order Aptera.
    Order Orthoptera: grasshoppers, cockroaches, walking sticks.
    Order Neuroptera: may-flies, dragon-flies, caddis-flies, termites.
    Order Hemiptera: water-bugs, lice, scale-insects, plant-lice.
    Order Diptera: fleas, gnats, mosquitoes, flies.
    Order Lepidoptera: moth, and butterflies.
    Order Coleoptera: beetles.
    Order Hymenoptera: bees, wasps, ants, gall-flies, ichneumons.
  5. Arachnida: spider.

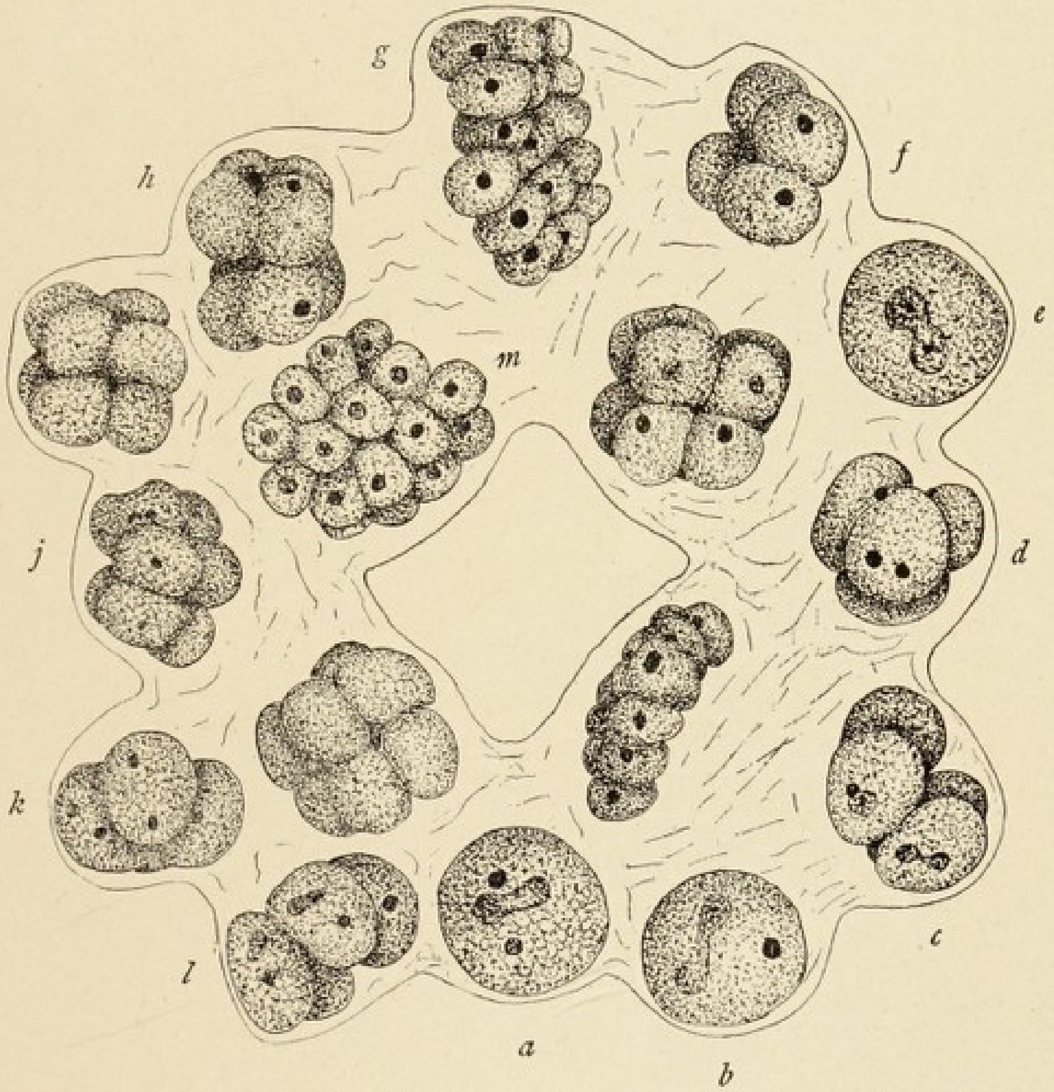
XI. Phylum Mollusca, 61,000 species.
  Classes 1. Pelecypoda: clams, oysters.
    2. Amphineura.
    3. Gastropoda: snails.
    4. Cephalopoda: squid, devil-fish.

XII. Phylum Chordate.
  Subphylum 1. Adelochorda.
    2. Urochorda: tunicate, 1300 species.
    3. Vertebrata.
      Acrania: amphioxus.
      Craniate.
        Classes 1. Cyclostomata: lamprey.
          2. Pisces: fishes, 13,000 species.
          3. Amphibia: salamander, frog, toad, 1400 species.
          4. Reptilia: horned toad, lizards, snake, turtle, alligator, 3500 species.
          5. Aves: birds, 13,000 species.
          6. Mammalia: dog, cat, sheep, seal, rabbit, monkey, man, etc., 3500 species.

Intermediate Types.—There are no sharp limits to the several phyla, so that there are a number of animals that fall in between or are grouped in an appendix to a given phyla. Some of these intermediate forms are interesting because they show how a higher form may have come into existence. This becomes a problem of great interest when the transition between the *Protozoa* and the next higher form, the many celled *Metazoa*, is made. In the unicellular animals the whole life is carried on within the limits of a single cell. Differentiation of work or structure is lacking, for the whole cell participates in the digestion of food, in metabolism, and reproduction. The hydra is a type of the slightly higher animal where there is a differentiation into at least two tissues, each of which carries on certain of the vital processes necessary to the existence of the hydra. There is not only more than one cell but there is a certain amount of differentiation in the work assigned to the cells of the ectoderm and endoderm. The cells of hydra are united and assigned to certain duties, so that the problem is to find in some of the intermediate types a tendency to merge the identity of the single cell into that of the organism, and at the same time a tendency to exhibit differentiation.

The *Colonial vorticellidæ* consist of a number of like individuals arranged in a tree-like fashion. Each individual is independent in all vegetative and reproductive functions. The cells are similar in size. These animals are termed colonial protozoa, but there is the beginning of cohesion of the cells (Fig. 83.)

FIG. 121

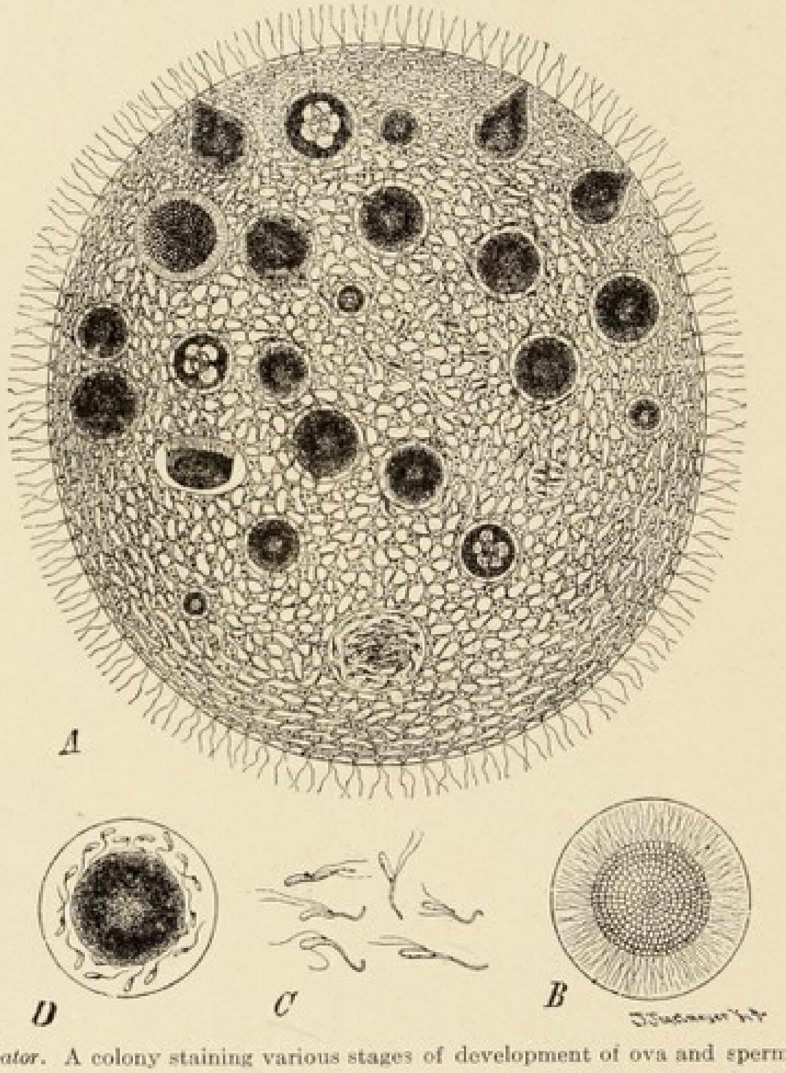


Gonium pectorale in reproduction. Each of the sixteen cells of the colony is dividing to form a daughter colony of sixteen cells. (After Calkins.)

Gonium is a sixteen-cell organism in which the cells are all alike, but united into one common body. Each cell eats, breathes, reproduces, etc. The cells are held together by their own gelatinous secretion. During the reproductive period the cells separate and act like unicellular organisms. This organism shows the first step in the union of cells, although it is not permanent (Figs. 83 and 121).

Volvox is an organism consisting of a number of cells varying with the species from five hundred to fifteen thousand. The cells are arranged in the form of a hollow sphere and are separated from

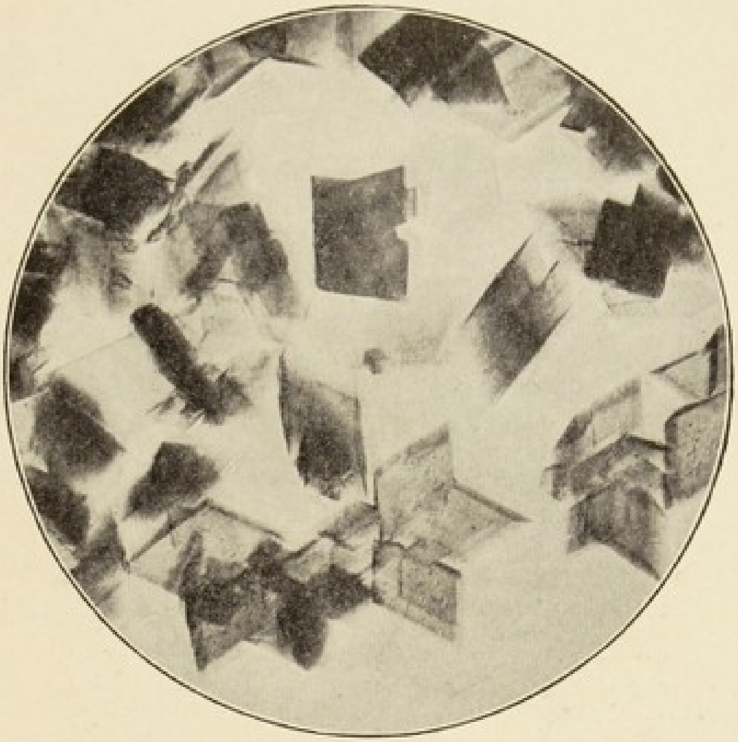
Fig. 122



Volvox globator. A colony staining various stages of development of ova and sperms (× 165). *B*, bundle of sperms formed from division of a single cell (× 530); *C*, sperms (× 530); *D*, egg cell surrounded by sperms in the mucilaginous membrane (× 250). (From F. Cohn.)

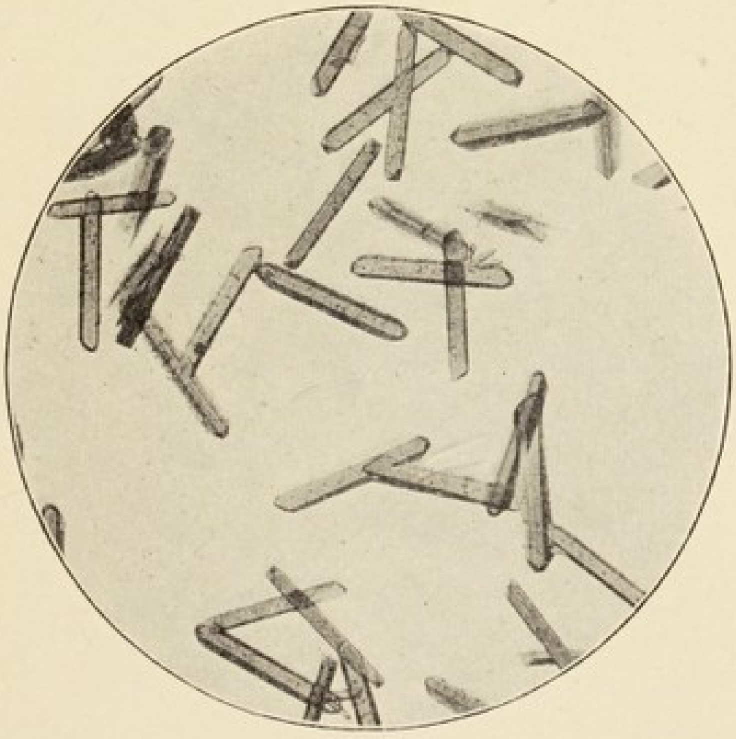
one another by a jelly-like substance through which pass fine protoplasmic threads. The cells are all much alike until the reproductive period, when certain cells become specialized into eggs or sperms. During the growth of these reproductive cells they are nourished by the other cells in volvox. Before one can recognize that there has really been a differentiation of cells the process must have been preceded by the formation of cells of different sizes.

FIG. 123 [1]



Shad.

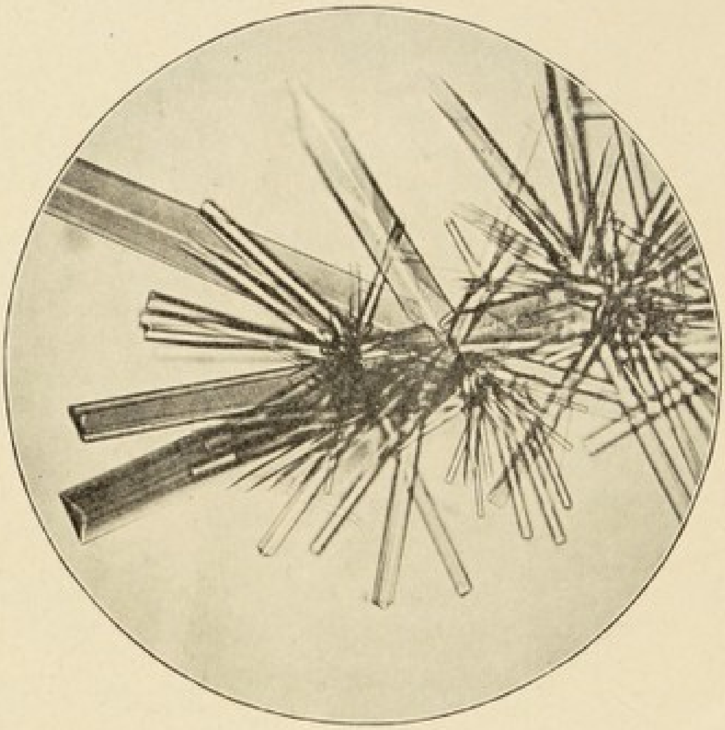
FIG. 124



Necturus.

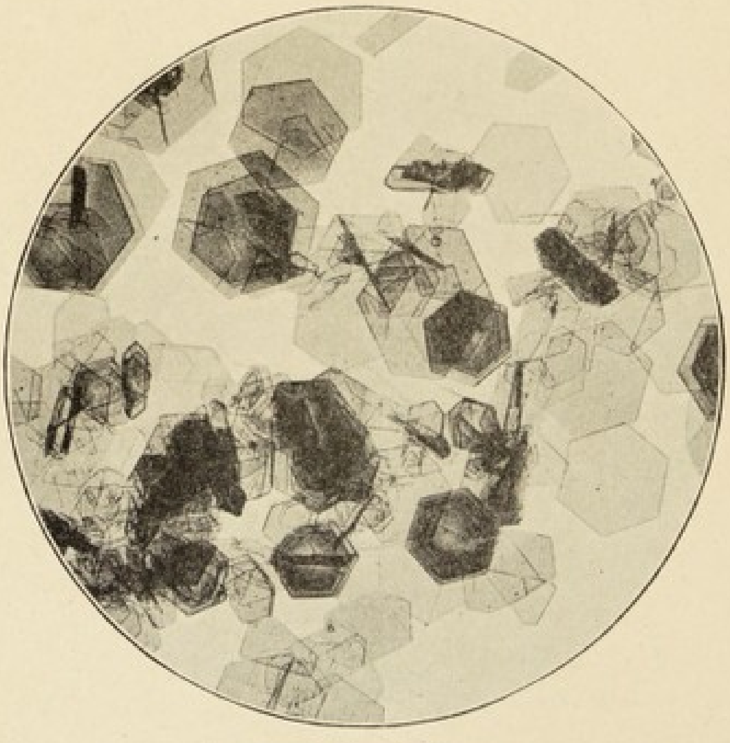
[1] Figs. 123 to 128 are various forms of oxyhemoglobin crystals. (E. T. Reichert.)

Fig. 125



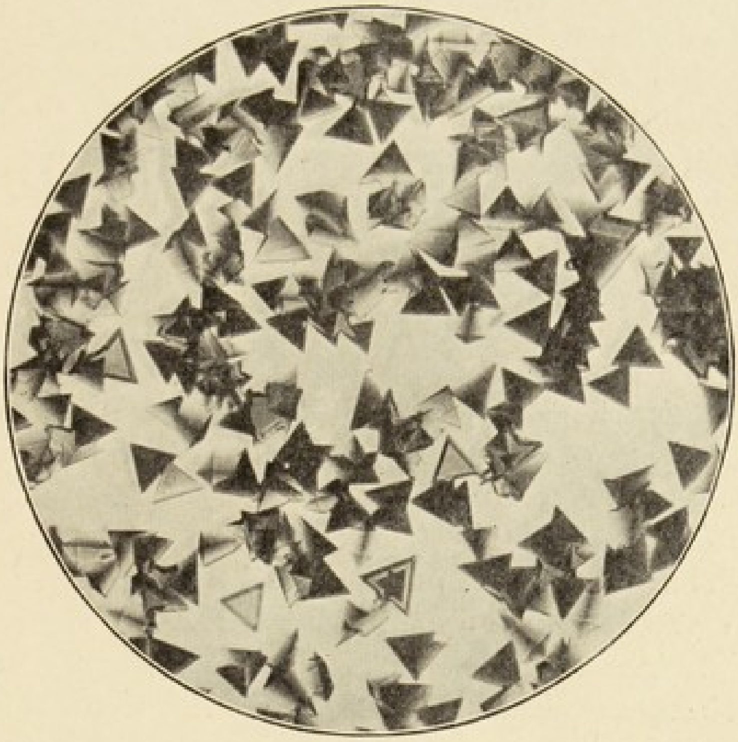
Cat.

Fig. 126



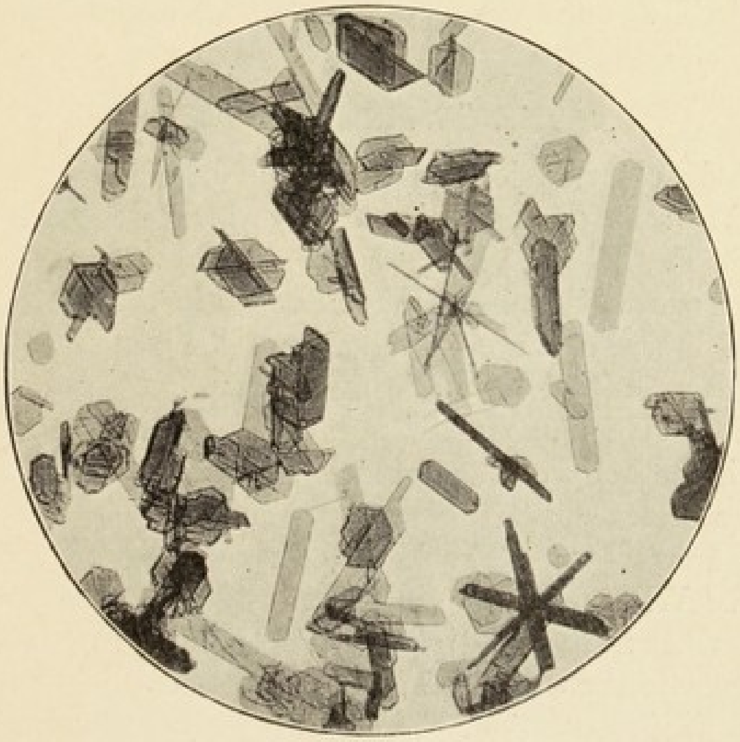
Red squirrel.

Fig. 127



Guinea-pig.

Fig. 128



Rat.

This means that unequal cell division is an accompaniment of differentiation. After the cells of volvox have produced and nourished germ cells until they can in turn produce new volvoxes they die.

In these examples given, and many more might be included, there is an obvious transition from the simple to the complex state. The cells tend to become more divergent in structure with an accompanying unification. "For efficient advance in the life scale integration and differentiation must go hand in hand." The higher animals are those in which integration and differentiation have been carried the farthest.

Blood Relationship.—Accompanying the differentiation of animals into the many phyla there has undoubtedly been a physiological divergence. Under some conditions this divergence is expressed in definite chemical reactions, such as the form of the crystals of the hemoglobin; the crystals of the species of any genus belong to the same crystallographic system, thus affording a critical test of relationship. The difference in the rapidity of the coagulation of the blood shows certain definite peculiarities. It takes from five to eight minutes for the clot to start in the blood of dogs and sheep; twelve to sixteen minutes in the pig; fifteen to eighteen minutes in the horse; and twenty-five to thirty minutes in the bullock. Blood relationship is a phrase used to express the physiologicochemical resemblances that exist among different kinds of animals.

THE "WORM" GROUP

In all of the older zoölogies there are included under this general term of "Worms" the animals that are arranged in this chapter under phyla IV, V, VI, VII, and IX. There was no real relationship, but the several members looked like worms and were so classed. They all lack well-differentiated body regions, such as a head for example. Some of the parasitic members will be described in the chapter on Parasitism. For the purposes of understanding the plan upon which the body of the worm is organized the common earthworm is the best.

External Morphology.—The body of the earthworm is long and cylindrical. When crawling it constantly keeps a given surface in contact with the ground; this surface is known as the ventral, and the opposite the dorsal. The earthworm is said thus to possess dorsoventral differentiation. There is no well-defined head, trunk, or tail. The mouth is located on the anterior end, and internally there are structures which are usually confined to the head region, and so the earthworm is said to have anteroposterior differentiation. The most conspicuous external structural feature of the earthworm is the presence of successive rings varying only in size. These rings are termed somites, and are the external expression of important internal arrangements of the organs. Animals which have somites are said to exhibit metamerism. This tendency to have the same structure repeated must have taken a firm grip on all of the animals that have evolved from the worm stage, as evidence of this plan of structure is continually cropping out. Metamerism is found in all of the arthropods and vertebrates, including man. For this reason alone the earthworm should be studied, as it helps one to understand many otherwise strange structures, such as the segmental arrangement of the muscles in fishes and all vertebrate embryos. The vertebræ, the paired spinal nerves, and intercostal bloodvessels are good examples of metamerism in man.

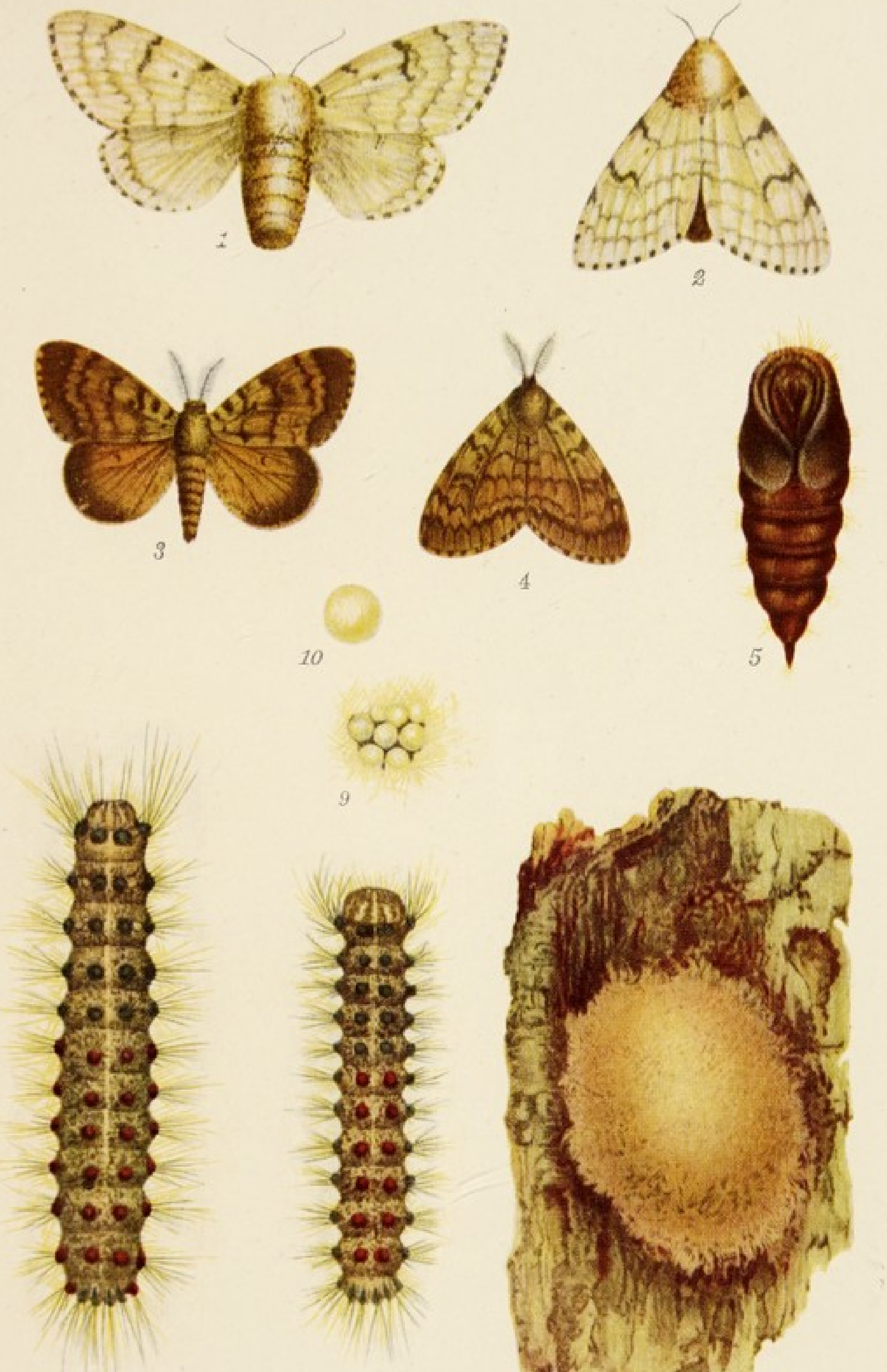
Habits and Special Senses.—The earthworms are nocturnal in habit and seldom leave their burrows in the ground except during the breeding season. During the daytime they are to be found near the opening of the burrows, but as dry summer comes on they move deeper into it. Earthworms hibernate singly or in numbers below the frost line. They are able to recognize the difference between day and night, although they do not have eyes even in a rudimentary sense. There are a number of specialized nerve cells in the skin that are connected with the nervous system. Structurally these nerve cells are all much alike, yet the worm is able to recognize day and night, certain smells, also jars, and is very sensitive to touch in the head region. The fundamental protoplasmic property of irritability is here concentrated in certain cells in the skin, but these have not become differentiated into the well-known eyes, ears, etc., of the higher animals, and yet the earthworm is able to act as if it had special sense organs. The earthworm has been studied a great deal because of its very simplicity in an attempt to understand just what is essential to a special sense. Here the physiological differentiation has preceded a structural differentiation. A similar case is found in the fact that we can detect the difference between hot, cold, pressure, touch, and pain in our own skin, although there is no appreciable structural difference between the nerve processes that enable us to recognize these several stimuli. On the other hand the well-defined eyes and ears enable all of the higher animals to have more accurate information in reference to their surroundings.

Organ Systems.—The organ systems of the earthworm may be briefly given because most of the parts are easily worked out in the laboratory. The plan of the body is that of two telescopically disposed tubes, a larger one typifying the body wall, and a smaller one the digestive tube. Between these two tubes there is a considerable space, the cœlomic cavity. The cœlomic cavity is partitioned by numerous dissepiments, thin sheets of connective tissue extending from the groove between the somites to the digestive canal. The blood flows through bloodvessels, well defined in the main, and the dorsal vessel acts like a heart in the way that it contracts and expands, thus forcing the blood along. The cœlome is also filled with blood, which circulates by means of small openings through the dissepiments; it contains numerous white blood corpuscles, which have the power of changing their shape and migrating through the tissues of the body. They are often called phagocytes. The waste leaves the body through the skin and well-defined nephridia located in each somite except the first two or three. The nervous system consists of a ventral nerve chain, with a ganglion for each somite. From each ganglion branches are given off. In the first two somites there are the following changes: the ganglion in the second somite is much enlarged, and are called the subesophageal; the two ganglia in the first somite are dorsal to the digestive canal, and are called the supra-esophageal ganglia or "brain." The ganglia of the first and second somites are connected.

Reproduction.—The earthworm has both male and female organs of reproduction, and because of this fact is designated an hermaphrodite. The ovaries are paired organs, minute, and pear-shaped, and situated in the thirteenth somite. As the eggs mature they escape from the ovaries and drop into the funnel-shaped openings of the oviducts, which open to the exterior on the fourteenth somite. The four pairs of spermaries are minute flattened bodies in the tenth and eleventh somites. The immature sperm cells leave the spermaries and are retained in three seminal vesicles until mature. The sperms are carried to the outside through a sperm duct opening on the fifteenth somite. In the ninth and tenth somites there are two pairs of small flask-shaped bodies called seminal receptacles. These bodies have no structural connection with any of the other of the reproductive organs.

Although the earthworm is hermaphroditic, it is not self-fertilizing, for there must be an exchange of sperms. This is effected in copulation, when the seminal receptacles are filled with sperms from another

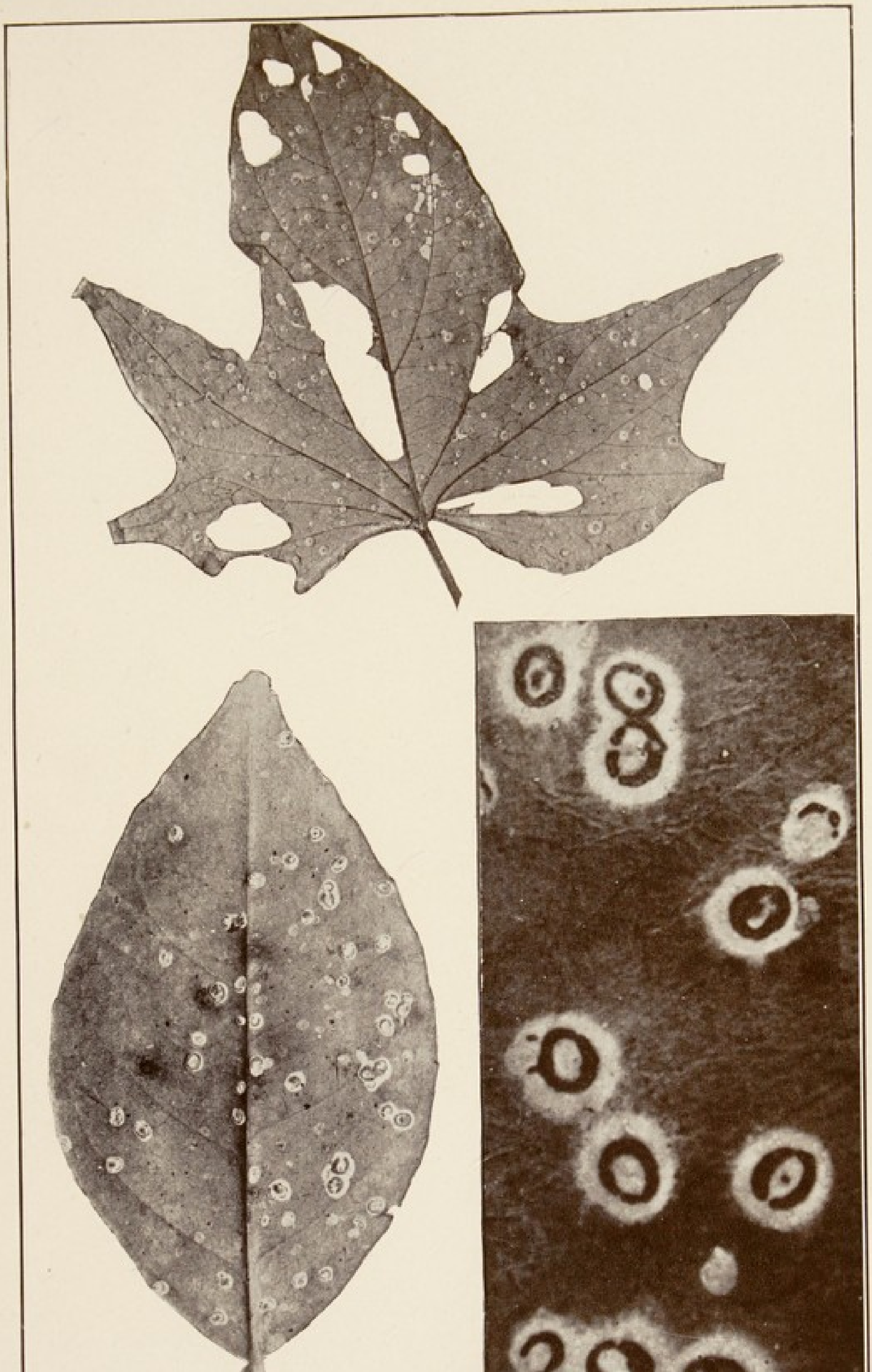
PLATE I



Gypsy Moth, Porthetria Dispar, Linn. (After Massachusetts State Board of Agriculture.)

1, female, with wings expanded; 2, female in resting position; 3, male with wings expanded; 4, male in resting position; 5, pupa; 6, dorsal view of one of the larger caterpillars, presumably a female; 7, dorsal view of one of the smaller full-grown caterpillars, presumably a male; 8, egg cluster on a piece of bark; 9, a few eggs greatly enlarged; 10, one egg still more enlarged.

PLATE II



Fungus-infected White Flies. (Morrill and Back.)

Red aschersonia developing on *Aleyrodes inconspicua* infesting sweet-potato leaves (top); red aschersonia infecting the cloudy-winged white fly (*Aleyrodes nubifera*), lower left; red aschersonia pustules, enlarged, showing mycelium and pycnidia (lower right).

animal. As the egg-laying period approaches, the clitellum secretes a viscid mucus, which hardens and toughens on exposure to the air, thus forming a membrane. This membranous girdle is pushed forward, receiving eggs from the oviduct and sperm cells from the seminal receptacles. In this way the eggs are fertilized by sperms from another animal. Finally the capsule is pushed from the head end of the worm, each end contracting as it leaves the animal to form a cocoon. In this cocoon the embryos grow, feeding on the enclosed food and devouring each other until but one usually reaches maturity.

Regeneration.—The earthworm is an interesting animal in which to study this power to regrow lost parts; for if any of the first seven or eight somites are removed, all will be regrown, but when more are cut off only this definite number form again. Thus if the first fifteen somites are removed, seven or eight will grow and the intervening ones will always be lacking, thus rendering the animal sterile. When somites are removed from the posterior end the regenerated part is at first composed of a very few somites. The terminal somite contains the new anal opening, and new segments are formed just in front of this terminal somite, the youngest being the one next to the end. This method of adding somites continues until all of those removed have been replaced. The worm cannot be split lengthwise and live. Hydra may also be studied to advantage in connection with this power of regeneration; or if hydra are not available, the flatworms, planaria, are excellent.

INSECTS

If the estimate of over 400,000 as the number of insects is but approximately true, they form by themselves a class of animals so numerous that one can never hope to know them all. In fact, one does not specialize in the study of insects, but selects some family or families in one of the orders of insects for his life-work. This can only mean that the general student must rely upon specialists for his details of classification. By many writers the insects are regarded as the highest of the invertebrates. Their body exhibits a high degree of specialization. This is especially true of the winged forms, which no doubt owe their numerical superiority to their powers of flight.

General Characters.—The body of the insect is divided into three distinct regions—head, thorax, and abdomen. In general the head bears the organs of special sense, prehension and mastication; the thorax, the organs of locomotion; the abdomen, the organs of reproduction. Metamerism is present, although greatly modified; the head contains at least five, the thorax three, and the abdomen ten somites. The body of the insect is covered by an epithelial layer which secretes a cuticle of varying thickness and flexibility. It is rendered hard by a deposition of chitin. A further characteristic of insects is that the young in most cases do not resemble the adult until they have undergone several changes known as metamorphosis. The metamorphosis is said to be direct when the young resemble the parents in hatching from the eggs, such as grasshoppers; and indirect when the young show no resemblance to the parent, such as the larva of the fly, the grub of the beetle, or the caterpillar of the moth.

Some Economic Aspects of Insects.—While the popular conception of insects is that they are injurious, a closer study shows them equally beneficial. Insects are very abundant and widely distributed. One entomologist gives this vivid account of their distribution: "It has been truthfully said that insects have established a kind of universal empire over the earth and its inhabitants. Minute as many of them are, and insignificant in size to other than naturalists, yet, in combination, they have desolated countries and brought famine and pestilence in their train. If unrestrained power could be given them, all counter-checks removed, and they were left to attack us in our person, food, clothing, houses, and domestic animals, the consequent disease, poverty, exposure, and want, would in the end remove the human race from the face of the earth. Air, earth, and water teem with them; there may be claimed for them almost an omnipresence. They swarm in the tropics and find a suitable home in the Arctic regions. They abound in our homes, our gardens, orchards, fields, vineyards, and forests. In the vegetable kingdom they are found in the seed, the root, the stalk or trunk, the pith, the bark, the twig, the bud, the leaf, the blossom, the fruit, within or upon every portion of the vegetable organisms. They are parasites on our person and upon or within all of our domesticated animals. They attack and destroy fishes and birds. They have their natural home in many of our articles of food. No asylum is so secure that they may not intrude; no condition in life is exempt from their presence." (Lintner.)

Insects have been classified as injurious in the following ways: (1) As destroyers of crops and other valuable plant life. (2) As destroyers of stored foods, dwellings, clothes, books, etc. (3) As injuring live-stock and other useful animals. (4) As annoying man. (5) As carriers of disease. They are classified as beneficial. (1) As destroyers of injurious insects. (2) As destroyers of noxious plants. (3) As pollenizers of plants. (4) As scavengers. (5) As makers of soil. (6) As food (both for man and for poultry, song birds and food fishes) and as clothing, and as used in the arts.

Destructiveness of Insects.—The forest trees are subject to many insects. The hickory is said to afford maintenance to between 500 and 600 species and the pine yields food to over a 100 different kinds, and even the recently developed sugar beet harbors over 70 species. In 1910 Hopkins, of the United States Bureau of Forestry, estimated that the average amount of timber in the forests of the entire country killed and reduced in value by insects would represent an average loss of $62,500,000 annually. This is due to the killing of trees by insects; the damage by them to the wood of living, dying, and dead timber; the destruction of insect-killed timber by subsequent forest fires; the damage to fire-killed timber by insects; and the damage from decay resulting from insect injuries to the wood; all three have been more or less continuous for centuries and are still going on in the forest and woodland areas of this country. While these depredations are not always evident or important in all forests or localities, yet almost every year, somewhere in the forests of the country, there are widespread depredations. In every forest and woodland there is an ever-present but inconspicuous army of insects which require the bark, wood, foliage, and seeds of the various species for their breeding places or food. Thus the accumulated but inconspicuous injuries wrought during the period required for the growth of a tree to commercial size go far toward reducing the average annual increment below the point of profitable investments. (Hopkins.)

Insects as carriers of disease will be presented in the chapter on Disease.

Beneficial Work of Insects.—A single phase of this interesting side of insect activities must suffice. "The economic bearing of insect enemies of insects is very great, and perhaps this is, all things considered, the most important of the beneficial function of insects as a class. In the eternal warfare of organism upon organism, in the perpetual strife of species, one preying upon another, and that upon a third, the complications of relations of forms which determine the abundance of one species and the scarcity of another are nowhere more marked than among insects. In fact, to the student of insects who has followed out even a single chain of these interrelationships the thought must necessarily come that upon its organic environment, and especially upon its relations with its living neighbors of the animal kingdom, depend the chances of a species not only for increase, but for survival almost to no lesser degree than upon its inorganic environment. Temperature is the great factor which controls the geographical distribution of life, and temperature is at the back of all these apparent living first causes which control the abundance of a species in a given region, provided we trace them far enough. Yet these living causes, themselves affected by other living causes in an almost endless chain, sometimes, to all appearance, dwarf even temperature as a controlling factor. There is not a species of insect that has not its natural enemies in the guise of other insects; there is not one of these other insects which has not its own foes. From a single species of Bombycid moth, the larvæ of which frequently damage forests in Europe to an alarming extent, there have been reared no less than 60 species of hymenopterous parasites. From a single caterpillar of *Plusiæ brassicæ* have been reared 2528 individuals of a little hymenopterous parasite, *Copidosoma truncatellum*. Outbreaks of injurious insects are frequently stopped as though by magic by the work of insects, enemies of the species." (Howard.)

The modern method of combating the inroads of insects is to discover their natural enemies, plant or animal, and introduce these into the infected district. In this interesting study the period in the life history in which the insect is most injurious, that is, larval or adult, must be understood. The chief hope of eliminating the gypsy and brown-tailed moths is the successful introduction from Europe of their natural parasites.

Animals representing several of the great phyla of the animal kingdom have been considered thus far and others will receive consideration in the discussion of parasitism and disease.

CHAPTER XIII

THE PLANT KINGDOM

LABORATORY STUDIES.—As is the case in Chapter XII, there is unlimited opportunity for laboratory study, and the amount done will have to be determined by the needs of the course. It is expected that a thorough study will be made of at least one flowering plant.

Our Relation to Plants.—The lawn, the fields, the woods, the hills, all owe their attractiveness to plants. We are so accustomed to seeing them everywhere about us that we do not realize their presence until a barren tract or burned area comes to our notice. While some animals are carnivorous the most of them require plant food for sustenance. This means that all animals, including man, are dependent upon plants for their existence. The raw elements of the soil and air as already explained are the ultimate food of green plants. By studying the conditions under which plants live man has been able to bring about many changes which have resulted in the production of vast crops of cereals, potatoes, apples, etc. Plant fibers are used in our clothing and the lumber of trees in our houses. To the medical student plants are important in their relation to drugs. The vegetable drugs may consist of the entire plant or be extracted from some particular part as belladonna, which is derived from the root and leaves of the nightshade. In most cases the drugs are derived from the higher (flowering) plants.

Plant Relations.—Although plants cover the earth in vast numbers, the total number of species is not as great as in the animal kingdom, as there are only about 233,614 species of plants. What was said about the classification of animals can be repeated for plants, and the student finds the same system of nomenclature, the division into phyla, classes, genera, species, varieties, etc. There are also transitional forms of plant life that help one to understand how plants have been evolved in nature. Plants are sometimes grouped according to their manner of living into societies. This does not have reference to structural relations but rather to the way in which a number of different plants have come to be able to live in ponds, streams, and swamps; or on arid plains and hills; or in the usual conditions of the temperature belt; or upon other forms of vegetation as frequently occurs in the tropics. The special name of ecology is given to this branch of botany and it considers the effects of the various factors in the environment upon the plant as well as the social relations between plants. The ecology of the flower takes up the factors that affect pollination, such as wind, insects, etc.

The Plant Kingdom.—Largely from Bergen and Caldwell.

Phylum I. Thallophyta.
- Subphylum I. Myxomycetes: slime moulds, sometimes classed as animals.
- Subphylum II. Schizophyta. 2020 species.
  - Class I. Schizomycetes: bacteria.
  - Class II. Schizophyceæ: blue-green algæ.
- Subphylum III. Algæ.
  - Class I. Chlorophyceæ: the green algæ. 8950 species.
  - Class II. Phæophyceæ: the brown algæ. 1030 species.
  - Class III. Rhodophyceæ: the red algæ. 3050 species.
- Subphylum IV. Fungi. 64,400 species.
  - Class I. Phycomycetes: moulds and mildews.
  - Class II. Ascomycetes: mildews, cup-fungi, etc.
  - Class III. Lichens.
  - Class IV. Basidiomycetes: cup-fungi, rusts, etc.

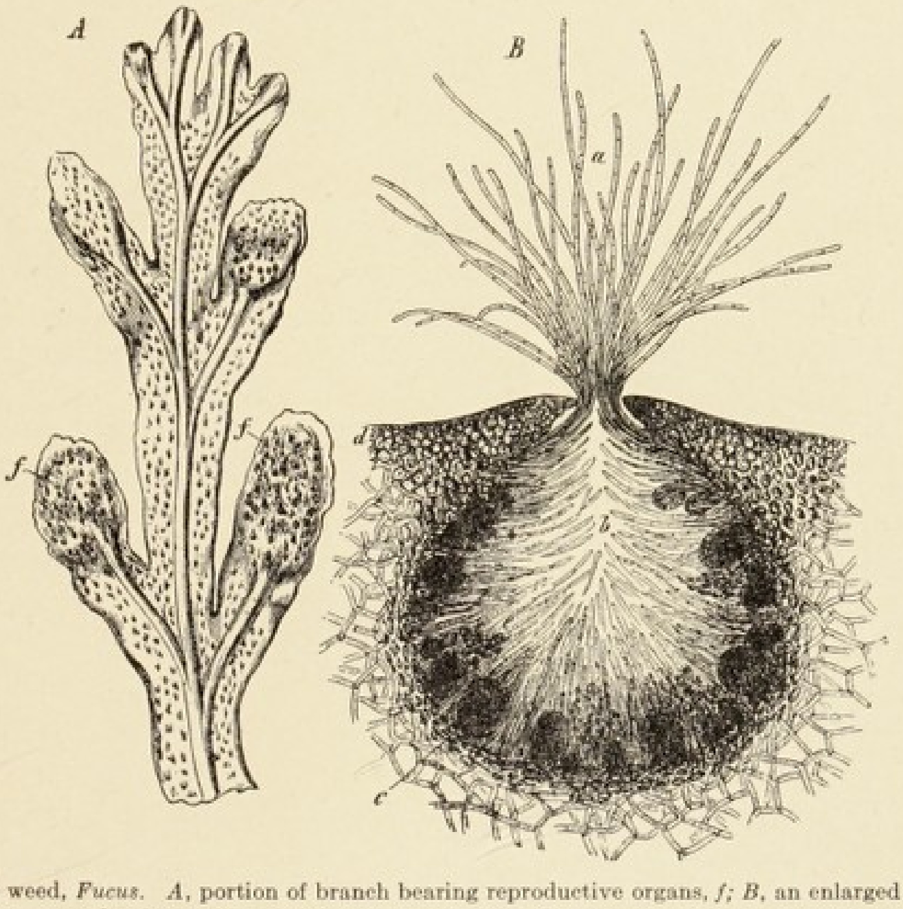
Phylum II. Bryophyta.
  - Class I. Hepaticæ: liverworts. 4000 species.
  - Class II. Musci: mosses. 12,600 species.

Phylum III. Pteridophyta.
  - Class I. Felicineæ: true ferns. 3800 species.
  - Class II. Equisetinæ: scouring rushes or horse-tails. 24 species.
  - Class III. Lycopodineæ: club mosses or ground pines. 700 species.

Phylum IV. Spermatophyta.
- Subphylum I. Gymnosperms. 540 species.
  - Order. Coniferales: pine, spruce, firs, etc.
- Subphylum II. Angiosperms.
  - Order I. Monocotyledons: corn, grasses, lilies, etc. 23,700 species.
  - Order II. Dicotyledons: hardwood trees, roses, etc. 180,800 species.

Thallophytes.—Probably the most important thing about a plant is the way that it gets its food. The normal plant, whether it be simple or complex, is one that can gain its food from nature. It is not a dependent organism. To this fundamental conception in regard to the nature of a plant should be added another, namely, that there has been an evolution in plants along divergent lines resulting in the formation of plant groups in which the genetic relations are complicated. In this process of evolution, however, some of the structural characters of the simple plants are to be found in the higher although greatly modified.

Fig. 129

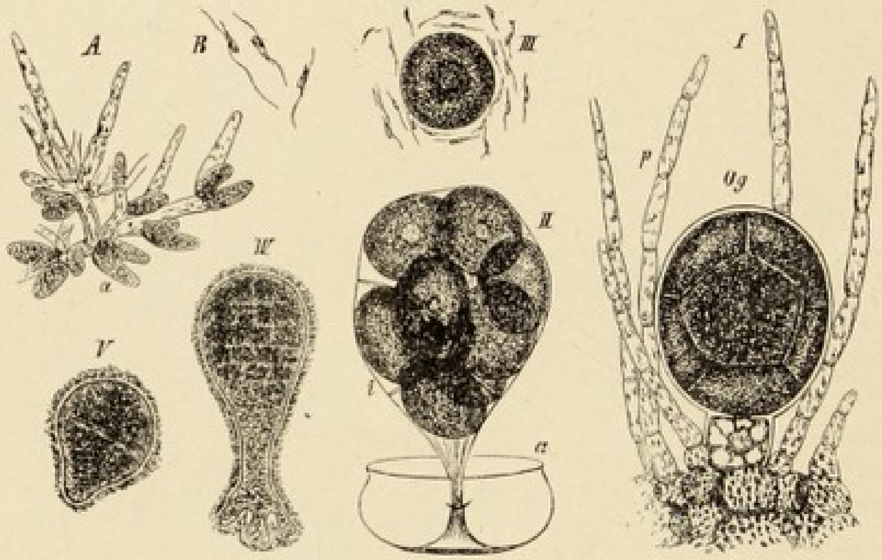


Rock weed, *Fucus*. *A*, portion of branch bearing reproductive organs, *f*; *B*, an enlarged section through a reproductive organ, the female conceptacle, showing egg cells, *c*; the cavity, *b*; false parenchymatic tissue, *d*. (After Thuret.)

In the thallophyte phylum are placed the simplest forms of plants. The body is a thallus and there is no root, stem, or leaf in the usual sense. The cells of the plant are similar and tissues are absent except as noted below. In some members of this group root-like processes, known as holdfasts, are developed. Many of these plants are fragile, having the cells united into a linear series, while others are like the brown kelp, tough sea-weeds, many feet in length.

As the classification indicates the thallophytes are composed of many normal chlorophyll-bearing plants, the algæ, and the divergent and dependent group of fungi many of which show definite algal affinities. The fungi live as parasites, saprophytes, and symbionts, and their relations to disease in plants and animals is so important that a separate course is necessary to present even the general facts of disease in fruits, in grains, in trees, in domestic animals, and in man.

Fig. 130

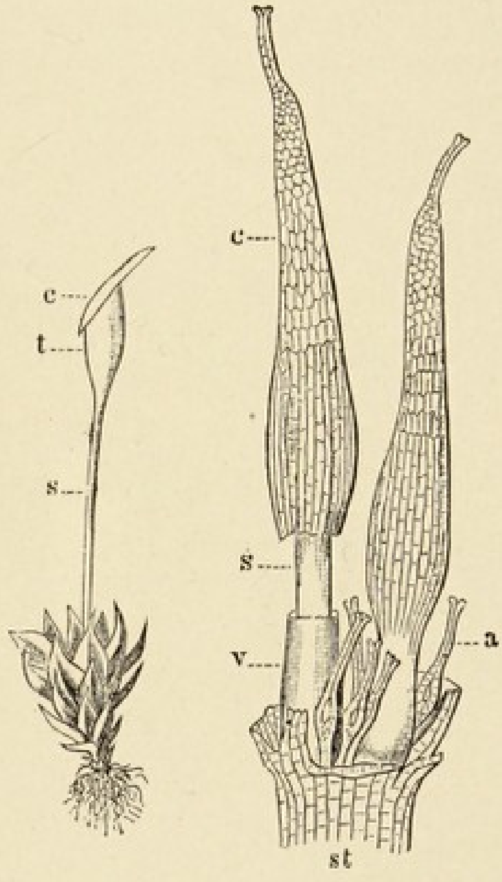


The sexual organs of *Fucus*. *A*, the antheridia, or male organs; *a*, borne on paraphyses; *B*, antherozoids or gametes; *I*, the oögonium or female organ, *og;* paraphyses, *p; II*, the oöspores (oöspheres) preparing to be set free; *III*, a free oöspore being fertilized; *IV*, *V*, young *Fucus* plants. (Rusby.)

The life cycle of this group is relatively simple as compared with the remaining phyla of plants, and this serves to be their chief distinguishing character rather than the nature of the thallus. For some of the higher plants have thalloid bodies and some algæ have a stem-like and leaf-like structure as complicated as that of mosses and a well-defined system of tissues. This group, then, is especially interesting because it shows the beginning of tissue differentiation and the origin and earliest expression of sex and sex-organs.

Bryophytes.—The life cycle of this phylum becomes more comprehensive, for there are introduced two stages—the sexual and sexless. This means that in the life cycle of every liverwort or moss two distinct phases of the plant play alternating parts. The sexual plant (gametophyte) contributes eggs and sperms and secures the fertilization of the egg; the other, the non-sexual (sporophyte) generation, grows out of the egg and in turn contributes non-sexually formed spores from which the sex generation takes its origin. This process is termed alternation of generations. In the simple bryophytes the sex plant is thallus-like, but this becomes a plant with a leafy stem in the mosses. The sexless plant begins as a simple structure that gradually develops into a complex plant bearing an elaborate spore case. The sexless plant lives as a partial parasite upon the sexual plant. In all instances the sexual organs of the bryophytes are many-celled structures, while those of the thallophytes are almost always one-celled.

Fig. 131

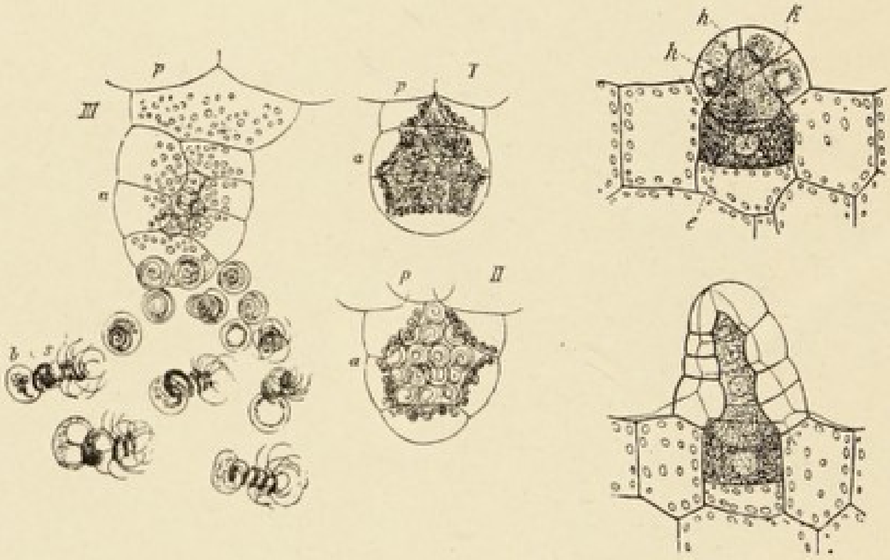


Showing the development of sporophyte of moss. *St*, apex of stem, bearing the female organs; *a*, the archegonia; from these, after fertilization, the young capsules spring, *C*, *S*, *V*; *C*, the calyptra, underneath which is found lid or operculum; *t*, the capsule; *s*, the leafless stem of sporophyte or pedicle. (Frank.)

The plants of this group show on the whole a more complete differentiation of the cells into tissues and in the higher forms leaf-like and stem-like structures appear. Specialized absorbing organs, the rhizoids, are developed and the plant tissues contain chlorophyll. The evolution of the bryophytes is closely associated with the change from the aquatic to the land habit. Here the parts of the plant become exposed to the drying effects of the air which require important structural adaptations. These differentiations foreshadow the general plan of structure of the higher plants.

Pteridophytes.—"The pteridophytes undoubtedly arose from a bryophyte ancestry where the sporophytes (sexless) generation, in some parents capable of doing chlorophyll work, developed a root system and vascular tissue, and taking the land habit became independent of the gametophyte. This was one of the most important forward steps in the evolution of the higher plants, for it gave the sporophyte complete freedom to live and grow to its maximum size. It marked a turning point in plant evolution, for after the sporophyte became the most complex and conspicuous phase of the life history, and the gametophyte, grew less prominent, until finally in the seed plants the sexual generation becomes actually dependent or parasites upon the asexual generation, a relation which is exactly the reverse of that between the gametophyte and sporophyte in the liverworts and mosses."

Fig. 132



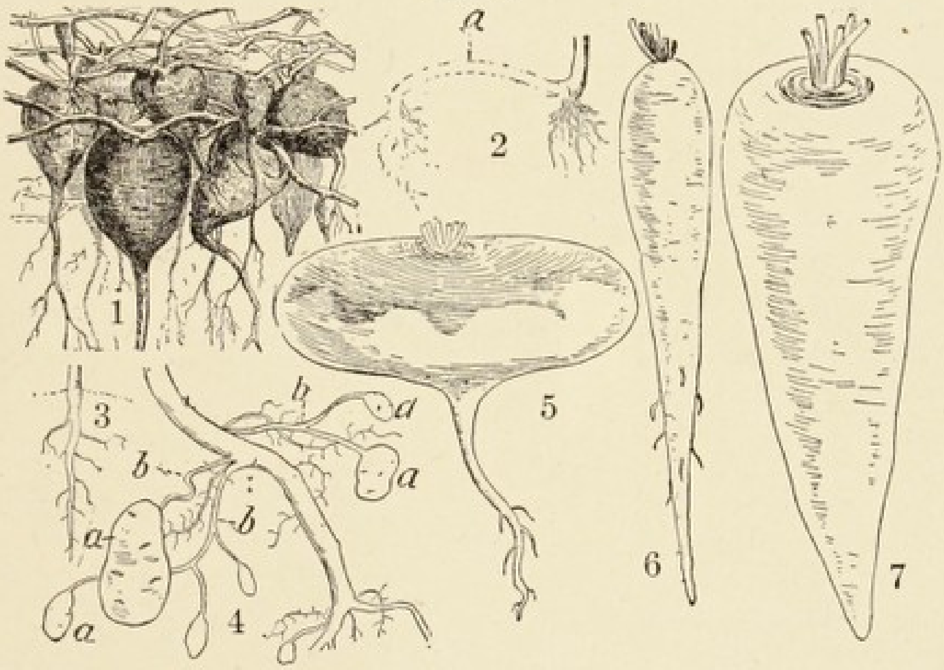
Organs of reproduction in the ferns. *I, II, III* (*p*), prothallium or gametophyte; *a*, the male organ, antheridium in various stages of growth of antherozoids, which in *b* are shown free and provided with cilia; *e*, oöspore or egg cell; *E*, the archegonium, developing into young fern plant, *h*. (Rusby.)

"After the sporophytes became independent of the gametophyte, the next important advance was the development of the lateral spore-bearing and vegetative organs called fronds. Then came the differentiation of the frond into vegetative leaves, given up entirely to chlorophyll work, and spore leaves (sporophylls) devoted chiefly or wholly to spore production. With this also came the massing of the sporophylls in cones, which was really the beginning of the structure called flowers in seed plants."

Closely associated in importance with the separation of the sexual and sexless generations in the pteridophytes is the production of two sizes of spores called respectively male and female spores, which is merely the beginning of a number of far-reaching developments in plants that reach their highest degree of specialization in the seed plants.

In the simple ferns the sexual plant is a thallus-like structure growing in such situations as to enable the sperms to utilize the water as a means of reaching the eggs. The higher members of this phylum, such as the Selaginella and Isoetes, have the sexual plant more or less mechanically retained within the tissues of the sexless plant and much degenerated, thus foreshadowing the condition in seed plants, but even in this relation water is the agency which carries the sperm to the egg.

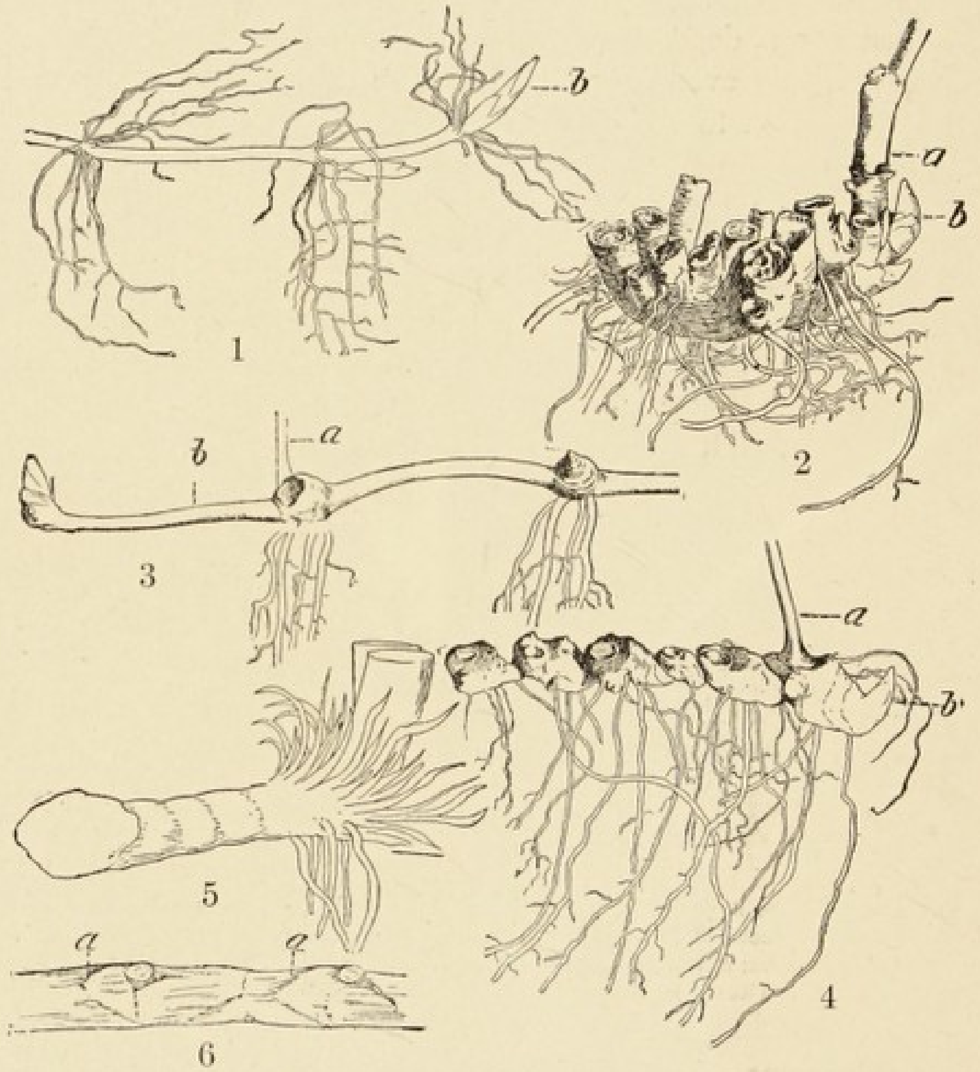
FIG. 133



1, tubercles of jalap; 2, death of first portion of stem, its subsequent growth maintained by cluster of secondary roots; 3, tap-root, with branches, of *Ambrosia;* 4, underground portion of potato plant: *a*, tubers; *b*, rhizomes, the roots seen intermingled; 5, a napiform fleshy root; 6, fusiform; 7, conical. (Rusby.)

Spermatophytes.—The division spermatophyta (meaning seed plants) contains not only the groups frequently called "flowering plants" but also other groups which do not have flowers in the popular sense of the word, for the reproductive organs are borne in cones or clusters which are not at all showy, but rather inconspicuous. These are, however, flowers in the scientific sense, as are also the cones of the horse-tails and club mosses. The spermatophytes have also been called phanerogams (meaning evident marriage), to distinguish them from all the lower groups of plants which were called cryptogams (meaning hidden marriage). However, this separation was made before the sexual processes of the lower plants were understood, for as a matter of fact they are much more evident than the complicated ones in the seed plants. The seed is a more significant structure in the group than the flower,

FIG. 134

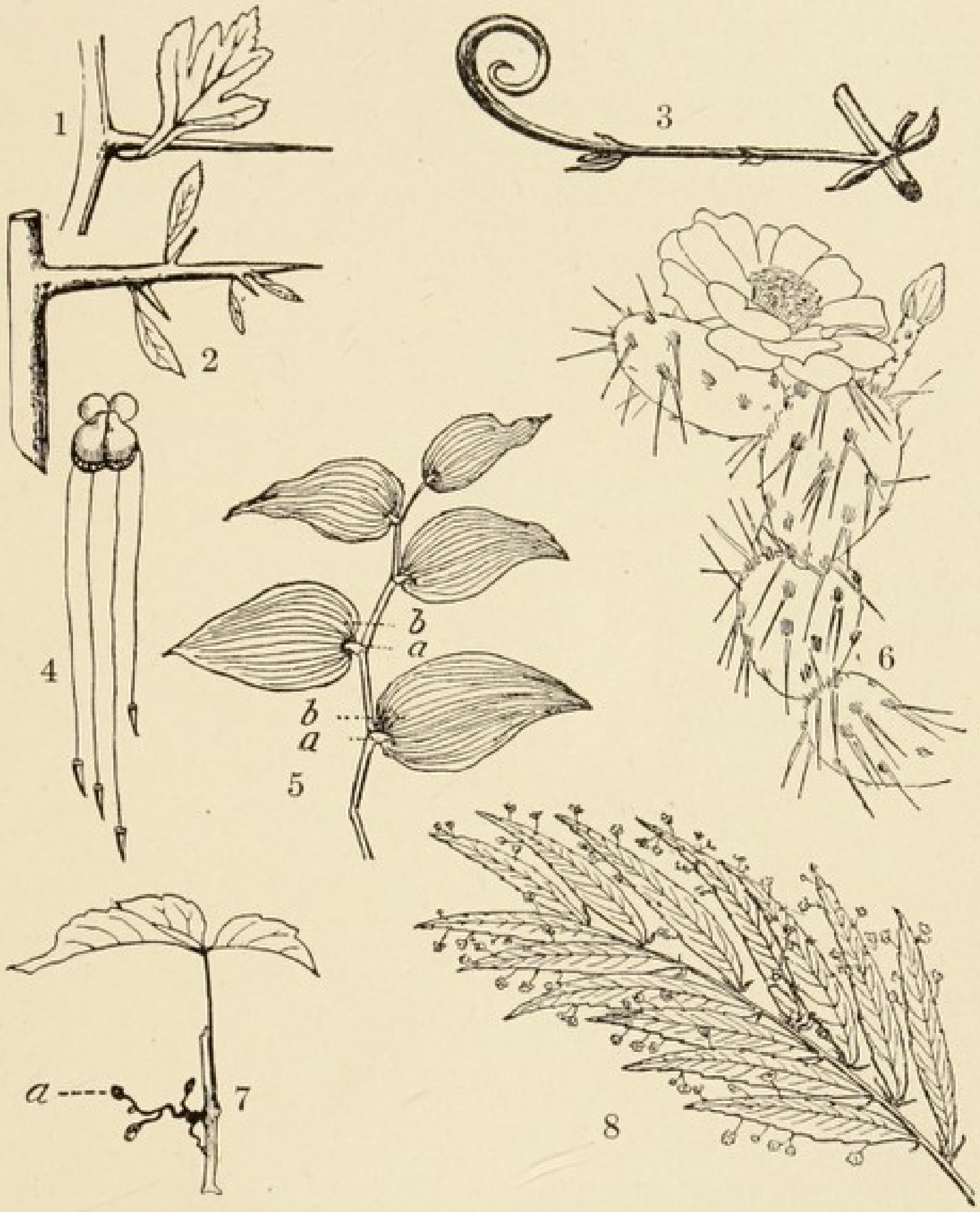


Forms of rhizomes. 1, *Convallaria*, with annular roots: *b*, terminal bud. 2, *Cimicifuga*, its cup-shaped stem scars much elevated; 3, *Podophyllum*, its internodes elongated; 4, *Polygonatum*, its cup-shaped scars depressed; 5, *Iris*, its roots aggregated at one end; 6, *Acorus*, with V-shaped leaf scars. (Rusby.)

so the name spermatophytes has in recent years come into general favor. The seed plant, like the fern, is a sporophyte. There is a gametophyte generation in the life history, which is, however, so much reduced in structure that it can only be understood by a careful study of the reproductive processes in seed formation.

The Seed.—"The importance of the seed in the development of plant and also of animal life can hardly be exaggerated. For the

Fig. 135



Illustrating modified stems. 1, branch converted into thorn; 2, the same becoming leafy; 3, branch of *Strychnos*, becoming a tendril; 4, stem of *Lemma*, modified like a leaf; 5, branches of species of *Asparagus*, modified as leaves; 6, condensed stems of *Opuntia;* 7, branches of *Ampelopsis* metamorphosed into disks; 8, branches of *Phyllanthus*, modified like leaves, but flower bearing. (Rusby.)

plant it furnishes one of the surest means of reproduction not only because of protective structures, means of dispersal, long vitality, etc., but also because the embryo plant is carried so far forward in its development that it is able to take root and establish itself at once. And further to aid the embryo, the seed is a storage organ of the most condensed forms of food material found in plants. In this respect, also, the seed has proved a most important influence in shaping the habits and in a large measure the evolution of some forms of animal life; for the highest groups of animals live to a very great extent directly or indirectly upon food stored in seeds and certain fruits, finding there some of the richest and most nutritious proteid and carbohydrate foods." (Bergen and Davis.)

Fig. 136

1, *Digitalis* leaf, with produced base, rounded apex, reticulate venation; 2, apiculate apex; 3, cuneate base (white oak); 4, cordate and produced base (violet); 5, sagittate base (*Polygonum*); 6, auriculate base (*Aster*); 7, hastate base (*Rumex*); 8, oblique base (*Datura*). (Rusby.)

The male spore of the pteridophytes is the pollen grain of seed plants and the female spore is the embryo sac. In order that fertilization may take place an outgrowth of the pollen, the pollen tube, penetrates the tissues separating the embryo sac from the outside world and thus one of the sperm nuclei is brought in contact with the egg nucleus. The spermatophyta have the most perfect expression of root, stem, and leaf found in any plants. It was but a short process to perfect the formation of the seed already anticipated, and so the members of this group have become differentiated in solving the life cycle problem with the result that they have become expanded into a multitude of forms following two lines of evolution, one the monocotyledons in which the cat-tail flag may be thought of as the lowest and the orchids as the highest; and the dicotyledons, in which a similar primitive and recent display is represented by such plants as lizard's tail and the crowning group of composites.

Fig. 137

1, flower of *Pulsatilla*, subtended by epicalyx, with calyx of 6 sepals. *a*, torus; *b* and *c*, rudimentary or aborted petals; 2, flower of *Adonis:* *a*, petal; *b*, pistil; *c*, stamen; 3, unguiculate petal of *Dianthus:* *a*, unguis or claw; 4, flower with its carpel partly reverted to the leaf form. (Rusby.)

Organs of the Flowering Plant.—In the simpler forms of plant life the structures are so elementary that it is difficult to make out distinct organs. They are able to feed, grow, reproduce their kind and adapt themselves to a distinct environment without having definite organs. In this sense they are similar to the protozoa and simpler metazoa. But in the higher plants the body has developed distinct organs that minister to the plant. They may be grouped as vegetative and reproductive. The vegetative are the root, stem, and leaves, while the reproductive are the flower, which is but a modified shoot adapted to reproductive purposes. In these several organs are found the many drugs and at this point students in pharmacology and pharmacognosy begin their course.

CHAPTER XIV

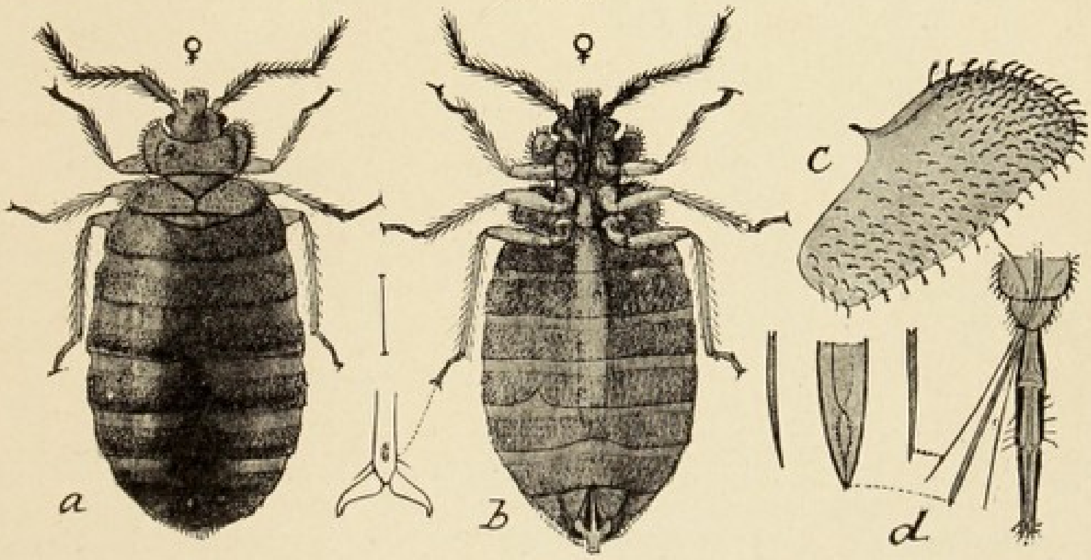
SOME BIOLOGICAL ADAPTATIONS

Laboratory Suggestions.—Material suitable to illustrate this chapter may be found all through the course. The careful study of the frog usually reveals several kinds of parasites. The grasshopper and fish are nearly always harborers of parasites. The galls on plants, especially golden rod and oak trees, illustrate another phase of parasitism. The blood of any vertebrate is liable to have parasites.

Adaptation.—It is so difficult to mark off sharply the habits of organisms that it seems better to describe briefly some of the general conditions of adaptation. Each organism is limited in size and occupies a definite place in nature. The mere fact that this statement can be made implies that every organism is fitted to live in the place where it is found. Here surrounded for the most part by inanimate particles it lives its life. In one sense all nature constitutes its environment, but in a more restricted sense its immediate surroundings most deeply affect the various parts of the organism. Animals and plants are adapted to living in the water, on land, at sea level, on the mountain top, in the tropics, in the Arctic circle, in short, everywhere on our globe. But when man attempts to transfer plants and animals from one environment to another then the force of adaptation is realized. Most organisms become so thoroughly adapted that they cannot be transferred: the polar bear cannot live in the tropics for any length of time, the palms of the South die in the North unless housed. Examples could be indefinitely multiplied. One must keep in mind that each organism begins life in a single cell and that each organ as it assumes its work in the body of the organism gradually acquires certain physiological ways of working that add to the success of the whole organism with the results that adaptation is really a problem that must go to the protoplasm for its last analysis. Besides the changes involved in day and night, in temperate regions there is the seasonal adaptation, especially of the winter when the leaves are shed and the birds migrate to a warmer clime. The habits of each group of animals indicate that some prefer the night time for foraging while others do best during the day. At the bottom of all of these varied and numerous adaptations are specific differentiations in cell structure or cell physiology.

With the diversified physiographic conditions that obtain on the globe, it is to be expected that organisms will have developed many unusual methods of gaining a livelihood. The profligacy of nature in producing such vast numbers of individuals has resulted in her constantly turning loose more individuals than can find a foothold. The struggle for food is the most satisfactory explanation for the origin of some of these peculiar habits. Coöperation began in nature with the first pair of animals. This pairing springs from a universal necessity for all of the higher animals, namely, to insure the perpetuation of the species; for this the united energies of the two are required, especially where parental care exists. This means that the individual is not the social unit but the two animals that have paired either temporarily or permanently constitute the unit. In those animals that exercise no care of their young, there is usually an enormous drain on the parents in producing a large number of eggs and sperms which compensates in part for the lack of parental care. The necessity of having a place to live whether it is temporary or lasting implies ownership of that place for the time being; with some animals this simply means a limited occupancy, while with others possession is exclusive. The social unit, the pair, prevails in all classes of animals above the protozoa; and as the scale of complexity is ascended, it becomes more predominate.

Fig. 138

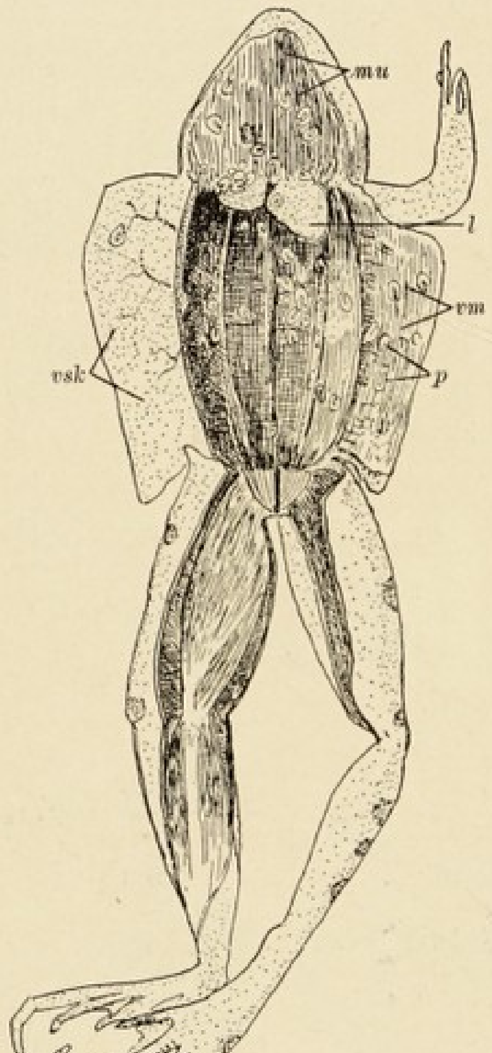


The bedbug (*Cimex lectularius*). *a*, adult female gorged with blood; *b*, the same from below; *c*, rudimentary wing pad; *d*, mouth parts. *a* and *b*, much enlarged; *c* and *d*, highly magnified. (Marlatt.) Relapsing fever and kala azar are carried by the bedbug. (Rosenau.)

PARASITISM

The term "parasitism" was employed at first to describe those who sat around the tables of the rich in ancient Greece receiving their invitation through fawning and flattery. When the word was used to describe a similar relation among animals it was applied to animals that have taken to a thievish existence as unbidden guests in or on other organisms. Our knowledge of the facts of parasitism goes back into the sanitary codes of the Jews and Egyptians which declared as unclean such animals as the pig, rabbits, and dog, animals now known to be especially infested with parasites, and it is only within recent years that our sanitary laws have made the pig a clean meat for all. During the middle ages the school-men perplexed themselves with quaint hypotheses as to the time and place of the introduction of parasites into man. The idea that life could spring suddenly into existence was a fruitful suggestion for their origin, and it was not until the eighteenth century when the life history of one of the flesh-eating flies was completely worked out that scientific men began to suggest that parasites arose from free-living animals. This discovery led to a truer knowledge of the origin of parasites and from then on until today there is not a parasite known that cannot be traced in origin to some antecedent life.

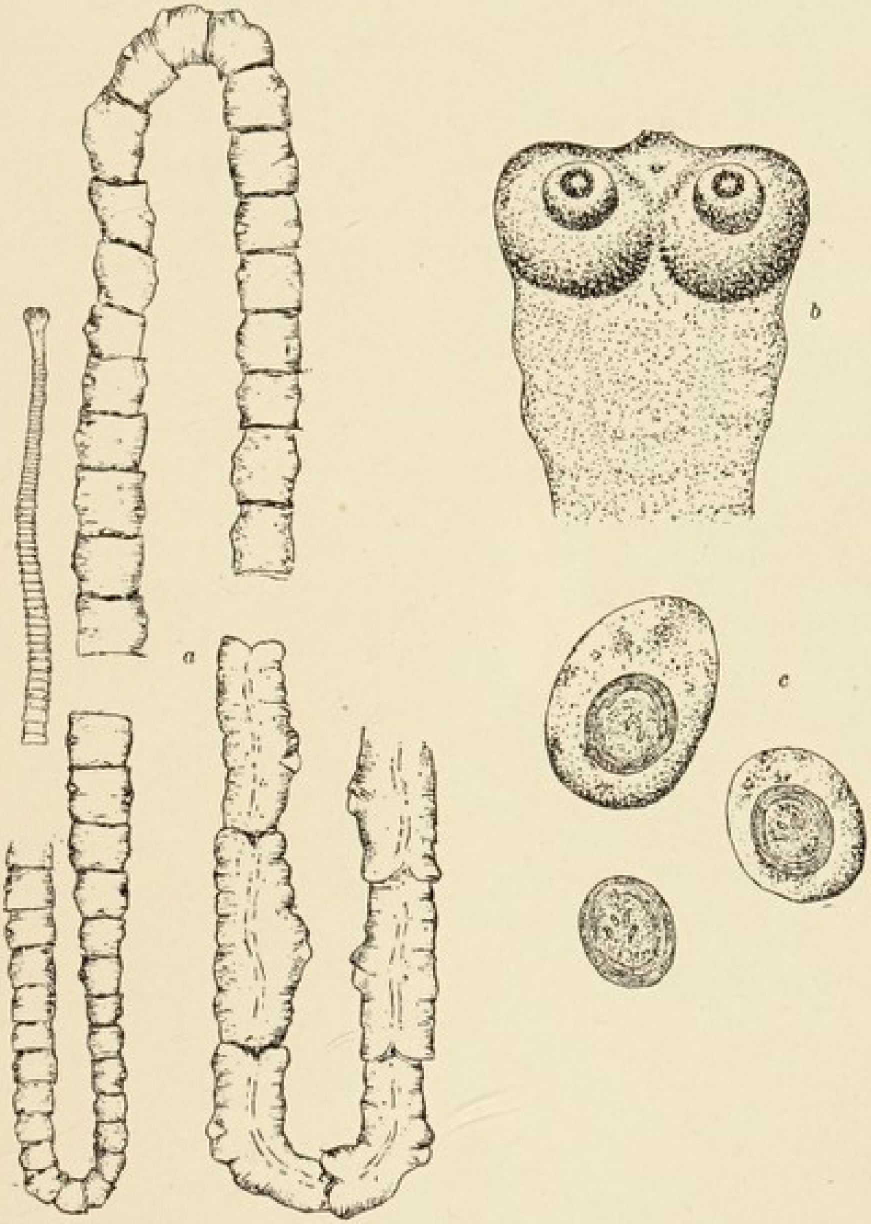
Fig. 139



View of the ventral surface of the frog after the removal of the cœlomic viscera, showing numerous encysted flukes, *Clinostomum marginatum*. *l*, lung; *mu*, muscles of floor of mouth; *p*, flukes in place; *vm*, ventral muscles of cœlomic cavity; *vsk*, skin of ventral cœlomic wall. (Osborn.)

Classification of Parasites.—Biologists would be glad if they could work out an exact classification for the plants and animals that lead a parasitic life, but such instances as the following show how futile is the attempt: Animals like the horse-flies and mosquitoes which come and go may be termed as *temporary;* while the bird-lice which pass their entire life on the bird are called *permanent.* The fleas, ticks, dodders, mistletoes, and others confine their relations

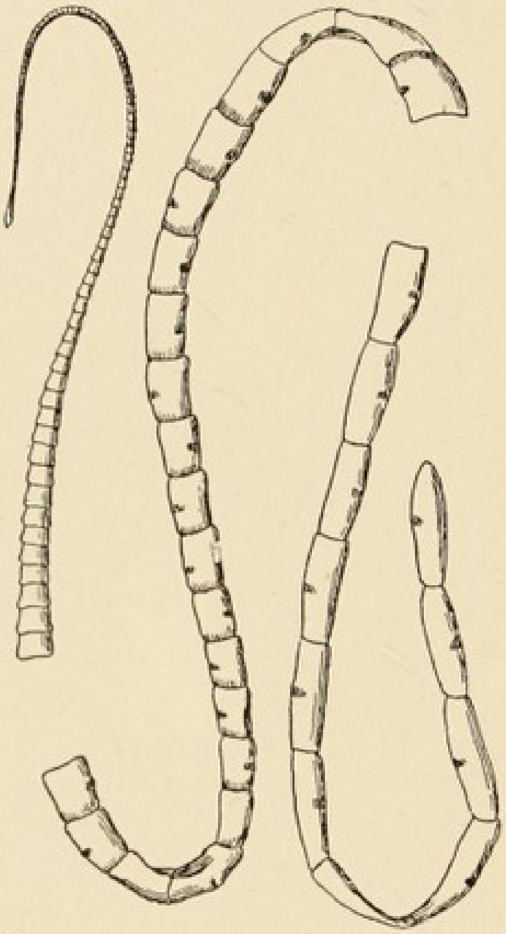
Fig. 140



Tænia saginata. a, natural size; b, much enlarged; c, ova much enlarged. (Simon.)

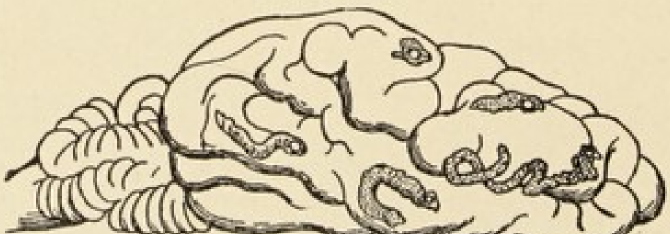
to the outside of their host, and the term *external* is applied; while the tapeworm of cat, dog, or man is entirely within the body and so should be called *internal.* Their life history affords another method of classification. The leech is parasitic in the *adult,* while the larva of the fresh-water clam always passes a part of its development encysted in the gills of some fish, typifying a class of animals

Fig. 141



Portions of an adult gid tapeworm (*Tænia cœnurus*). Natural size. (After Railliet, 1893, Fig. 146, p. 252.)

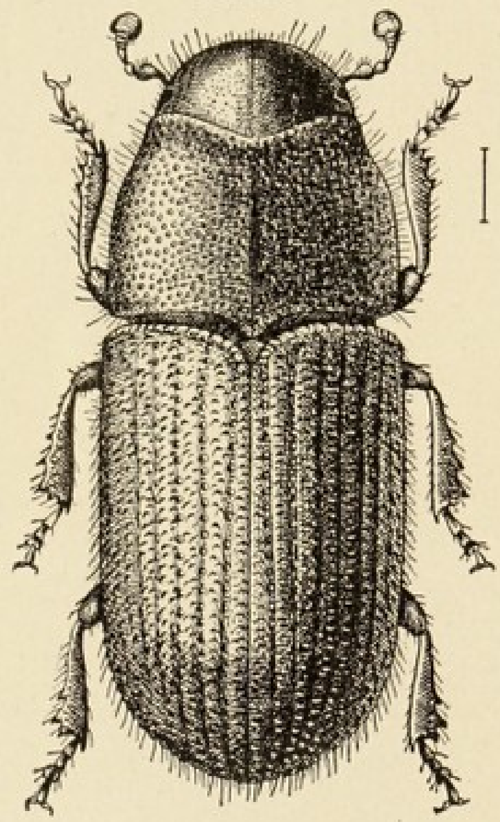
Fig. 142



Brain of lamb, showing the furrows produced by the migration of young gid bladder-worms, taken at a time immediately following the period of invasion, *i. e.*, from fourteen to thirty-eight days after infestation. Natural size. (After Leuckart, 1879, Fig. 81, p. 173.)

parasitic only during their *larval* existence. From this same standpoint there are those animals also which either *complete* their *life* in *one host* such as the pup-worms found in young seals, or those that demand *several* hosts. Of this latter class is the organism malaria which spends part of its life in the blood of man and the remainder in the body of the anopheles mosquito. Or the malarial parasite may be classified as one that is dependent for its existence upon its hosts, and is thus termed an *obligatory* parasite; while any parasite which temporarily lives within or upon a host and can exist without utilizing the parasitic habit a part of the time is called a *facultative* parasite. The parasitic bacteria belong in the main under this latter term. The effect on the parasite affords still another form of classification. Some parasites, like the leech, mosquito, or trichinella, show very little effect as a result of this habit; while the great majority are permanently and noticeably degenerated as a result of their mode of living. The most important aspect of this question is the effect of parasitism, first upon the parasite and then on the host. As a general statement, the parasitic habit tends to weaken the self-dependence of the parasites. This is shown in many ways other than the inability of the parasite to live alone and thrive. Some of the parts of the body actually disappear although present in the young animal. The marine crab is infested with a conspicuous example known as *Sacculina*. This parasite has a complete set of all the organ systems characteristic of its class while it leads a free-swimming life, but as soon as it becomes parasitic, its appendages, food-canal, sense organs, and nervous system are lost, the body consisting essentially of reproductive tissue, a system which never degenerates. The tapeworm has no alimentary canal and only the remains of a nervous system. Other examples could be given to show that there is an actual loss of organs that the parasites need when living alone. The parasite

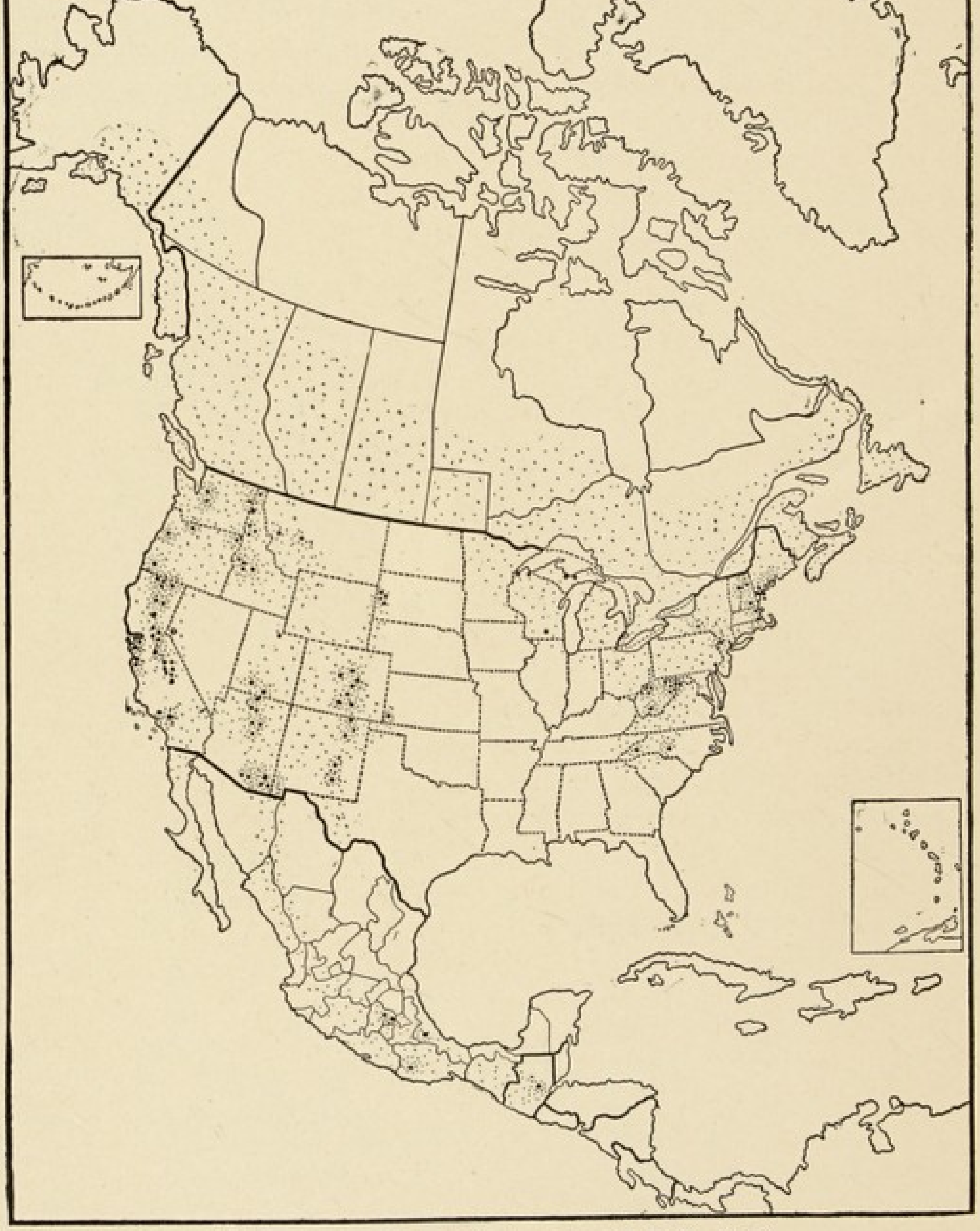
Fig. 143



Dendroctonus valens. Adult. (A. D. Hopkins.)

loses these parts because it has no use for them; thus failure to use an organ tends to its obliteration.

FIG. 144



Dendroctonus valens. Distribution map. (A. D. Hopkins.)

Extent of Parasitism.—It is a well-known fact that all of the larger animals harbor or may harbor many parasites, but as soon as careful studies are made the smaller animals are found to be parasitized, even to the protozoa. One recent expert says that "it is not a too sweeping generalization to state that every living thing, large enough to contain another living thing, is subject to invasion by parasites.

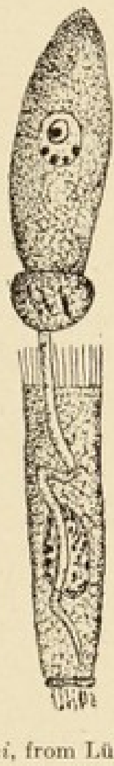
Fig. 145

Dendroctonus valens. Work in bark at base of stump. *a*, entrance and pitch tube; *b*, egg gallery; *c*, boring dust and resin; *d*, pulpal cell; *e*, pupa; *f*, larvæ at work feeding on inner living bark; *g*, exit burrows; *h*, resulting old scar or basal wound, often referred to as basal fire wound; *i*, inner bark with outer corky bark removed. (A. D. Hopkins.)

The protozoa, themselves single cells, often play the part of host to smaller protozoan cells, and parasites often infect the nucleus of ameba, paramecium, vorticella, and other types." It is difficult to make the word parasite convey an exact meaning for we know that many trees harbor hundreds of insects, that the fly, mosquito, and others occasionally bite us. From the fly to the tick is but a short step and the tick is surely a parasite. The sheep in the pasture feeding upon the grass and the fox killing mice for her young are in the broad sense living on other living things. These cases are not regarded as parasitism although the habit is essentially the same. The word parasite is best limited to such plants and animals as literally take up their residence for a time upon some other form of life which is the host. This means that the parasite is always smaller than the host although it may be a higher organism. In most instances parasites are simpler in structure than their host, as the tapeworm in dog, or the ameba in man.

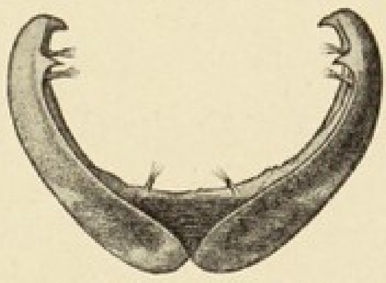
Protozoan Parasites.—The number and importance of the protozoan parasites is now recognized as very great and a literature of considerable proportions is rapidly accumulating. We may expect that in the next few years more will be added to our knowledge of this phase of parasitism than to all other phases. The parasitic protozoa have been grouped for convenience of description by Calkins into unnatural groups, according to their mode of life. Some are purely enterozoic, spending the entire life in the lumen of the digestive tract (flagellates like *Copromonas, Cercomonas, Herpetomonas, Crithidia*, etc.); others are cœlozoic, dwelling in the cœlomic cavities of the body (many gregarines); others are cytozoic, living throughout the vegetative period of life as intracellular parasites (*Coccidiidia*, in epithelial cells; *Myxosporidia*, in muscle cells; and intracorpuscular *Hemosporidia*); still others are caryozoic, passing into the cell body to find lodgement in the cell nucleus; such caryozoic forms are only specially adapted cytozoic types, but their habitat is always the same (*Cyclospura caryolytica, Nucleophaga amœbæ*, and in part *Cytoryctes variolæ*, and others); others, finally, are hematozoic, living in the blood (*trypanosoma, plasmodium, hemaproteus*, etc.). In many cases there may be modifications of these modes of life or combinations of two or more. Thus plasmodium may be hematozoic, cytozoic, enterozoic, and cœlozoic during some period of its life history in the mosquito or in the blood, and the terms are too indefinite to be employed in any way save for the purpose of description. In some cases special organs for absorbing food are developed, as in *Pykinia mobiuszi* (Fig. 146). The parasitic protozoa have developed other adaptive structures, especially the protective capsules which envelop the spores. When the parasite becomes sexually mature it fuses with another cell in conjugation, and fertilization is followed by spore formation. The spores thus formed do not reinfect the same host, but, contained usually in the lumen of the digestive tract or similar cavity of the body, they are finally carried to the outside in one way or another with the waste matter. Here, were it not for the protective coverings which they possess, they would soon be killed by exposure, but, protected by the resistant chitinous membranes, such spores resist drying and retain their vitality until again taken into a new host, usually by way of the digestive tract. Animals of gregarious habits are particularly subject to protozoan infection, the spores usually

FIG. 146



Pykinia möbiuszi, from Lühe. (After Léger and Dubosq.)

FIG. 147

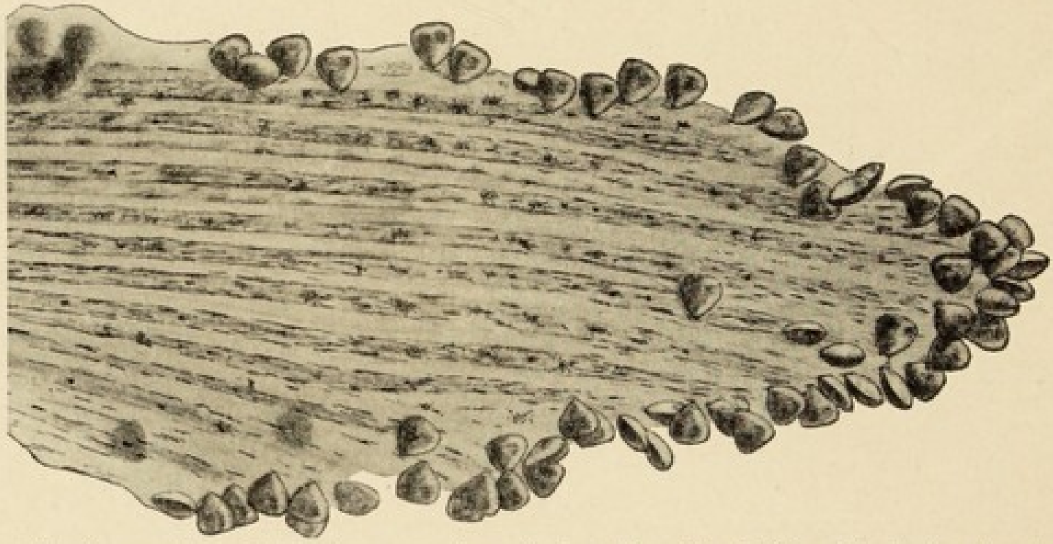


Axe-head glochidium of Lampsilis (*Protera*) *alata*, anterior end view. In the larval stage, the glochidium of certain fresh water molluscs lives from nine to thirty-six days as a parasite in fish and this is a necessary stage in its life history. (Le Fevre and Curtis.)

contaminating the food. In the intestine the germs of the organisms are liberated from their coverings and make their way by one means or another to the definitive locality where growth is possible. The so-called selection of locality is a matter of mere passive resistance on the part of the parasite, that part being selected where they are not destroyed by the reactions of the host, and where conditions of life are most satisfactory for nourishment and security. (Calkins, Protozoölogy, Chapter V.)

Parasitic Flatworms (*Platyhelminthes*).—The animals of this group have a very wide distribution, being found on land, in fresh water, the seashore, on the surface of the ocean, and even in the depths of the sea. A majority of the species are parasitic and in one phase or another live in animals. The tapeworms, of which there are many species, are found in fishes, frogs, snakes, birds, and mammals, including man. The head end of the body has developed either special hooks or suckers by means of which it is able to attach itself to the lining epithelium of the digestive canal. Constantly bathed in food in the process of being digested, they have but to absorb what they need. The result of this habit is to greatly reduce through disuse the organs of digestion, but the reproductive organs have become highly specialized. The body of the tapeworm is composed of segments, but these are not true segments such as occur in earthworms but are specially modified structures that contain large numbers of eggs and sperms. As soon as the reproductive products mature that segment containing them is

Fig. 148

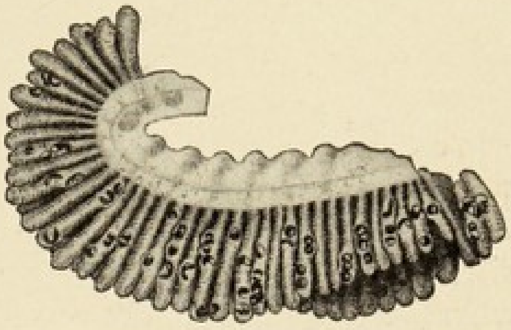


Fin of a carp about 3 inches long, seven days after infection with glochidia of *Anodonta cataracta*, showing complete failure of the overgrowth of fin tissue in all places where the glochidia are greatly crowded. (Le Fevre and Curtis.)

detached from the posterior end of the flat-worm and is termed a proglottide. The whole body may contain 850 proglottides. The ripe proglottides contain young embryos, and the whole structure passes to the exterior with the excreta of the host. Unless these embryo flatworms are eaten by the proper host, the pig in the case of one of the tapeworms that infests man, they die. But if they are eaten by the pig then the young tapeworm develops and soon bores its way into the muscles. Here they increase in size and develop into rounded cysts, remaining until they find their way into the intestine of man, where they become transformed into an adult tapeworm. In a similar manner the life history of the other flatworms might be described. They all show a large amount of degeneration and great powers of reproduction. The chances of tapeworms reaching maturity are very small and hence the necessity of the annual production of more than 100,000 eggs by a single tapeworm. Liver fluke is a member of this class.

Parasitic Roundworms (*Nemathelminthes*).—Many species in this phyla are likewise parasitic, among which are the trichinella, ascaris, and hairworms. They have a wide occurrence as parasites in the invertebrate as well as the vertebrate body. The life history of one of the species (*Bothriocephalus cordiceps*) will serve to show the habits of the group. This worm may reach a length of twenty inches and is found interlaced through the viscera of the trout in the Yellowstone Lake. The worms weaken the trout so that they are easily caught by the pelicans. In the alimentary canal of the pelicans, the worms reach maturity and portions of the worms containing eggs escape with the excreta. These are then eaten by the trout and the eggs give rise to new worms. When there happens to be a large number of these worms in the trout of this lake it has been estimated that each pelican feeding upon infested trout discharges over 5,000,000 of the eggs into the lake.

Fig. 149



Gill of yellow perch infected with glochidia of *Lampsilis ligamentina*, showing distribution upon the gill as a whole and the appearance of the cysts. (Le Fevre and Curtis.)

Each species has its own peculiar life-history which must be understood if it is to be destroyed. The pig is the second host of the trichinella which infests man. The careful inspection of pork and its thorough cooking are the safeguards which protect us today against this serious parasite.

Other Parasites.—The limits of this book and the purpose of the course do not allow one to give a full description of even the parasites representing each phylum. The relation of insects to disease will be considered in the next section as well as the parasitic bacteria. The fungi in the main are parasitic on both plants and animals as the rusts, blights, mildews, etc., well illustrate. If there were no checks in nature we should be hard pressed to protect ourselves from parasites, but, fortunately, parasites are infested by parasites and become diseased and die like all other organisms, so that there is preserved throughout the years a certain balance and the number of parasites does not seem to be on the increase even among animals uncared for by man.

The Spring-grain Aphis and its Enemy.—"Perhaps the interaction of these organisms, the perpetual restraint of parasites, and the effect of weather conditions on host and parasite may be best illustrated by the spring-grain aphis (*Toxoptera graminum*). This insect is present every year in greater or less abundance and is kept under control by its natural enemies, more especially by a tiny black and brownish four-winged fly (*Lysiplebus tritici*). The aphis gives birth to young from spring until fall, but during mild winter weather young are born as long as such weather continues, while the parasite remains dormant. The aphis begins to breed whenever the temperature rises to 45° or 50° F., during the day, while for the parasite it must be at least 10° warmer. Under normal weather conditions during winter and spring, the aphis starts in the spring from the eggs (winter eggs), and there are enough parasites, which have wintered over in the bodies of the aphis and emerged therefrom, to destroy so many of this aphis that it cannot increase rapidly enough to become injurious; consequently there is no trouble. But there comes a winter during which the temperature is warm enough to enable the aphis to breed continuously, and it thus becomes abundant by spring. If the weather turns cold during the winter the pest ceases to breed and serious depredations are averted, but if as is more often the case, a cold backward spring follows an abnormally warm winter, then the pest continues to breed while its enemies remain inactive and the result is that the former becomes so enormously abundant that wheat and oats are destroyed over large sections of the country before the parasite can increase sufficiently to overcome it."[1] (Webster.)

Natural Control of White Flies in Florida.—So far as known there is no true insect parasite of these flies which do so much damage to the citrus plant. The larvæ develop in the leaves which are often attacked by a fungus. "The first indication of the effect of the fungus on the larva of the white fly is the appearance of slightly opaque, yellowish spots, usually near the edge of the larva. In the early stages of infection the larva becomes noticeably swollen and appears to secrete a greater abundance of honeydew than normally. As the fungus develops, the internal organs of the larva appear to contract away from the margin, leaving a narrow circle, which then becomes filled with the hyphæ or mycelium. This circle

[1] Natural enemies of the citrus white fly. Bureau Entomology, Bul. No. 120, 1913.

becomes opaque and whitish, presenting a very characteristic appearance. Shortly after this the hyphæ burst out around the edge of the larva, forming a dense marginal fringe. This may form all around the larvæ at about the same time, or may develop at one portion of the margin sooner than at the others. The body of the larva at this time is plainly visible, but it is opaque and yellowish throughout. Death usually ensues, it is believed, before the hyphæ burst out. The fungus does not spread over the leaf to any extent but grows upward in a mass, gradually spreading over the larva. The fungous parasites thrive only under suitable weather conditions during a period of about three months each year. Their efficacy in destroying white flies under natural conditions is dependent upon the abundance of the insects; a period of excessive abundance always precedes effective temporary control. Bacterial diseases of the white flies are at present unknown but it is not improbable that they are the leading cause of mortality so far unexplained." (Morrill and Black.)

Symbiosis.—There is another set of relations, where two dissimilar organisms live together for their mutual benefit which is conveniently described by the term symbiosis, which simply means a living together. These relations occur between animal and plant, animal and animal, and plant and plant. For example, the lichen is a simple grayish plant growing on fences, stones, etc. If a botanist is asked to classify the lichen, there is usually some hesitation because the plant consists really of two distinct plants that have become so intimately associated that neither lives alone. The grayish color is due to the effect of the whitish fungi which grow over and around some green cells. The fungal elements belong to the same class of plants as the mushrooms, while the green cells are intimately related to the plant that often gives a greenish tint to the bark of trees and to the plants growing in ponds and known as pond scum. These two distinct plants live, intimately associated and it is difficult to see how the relation is harmful to either, and in fact it is regarded as decidedly beneficial. The second example is where two animals live together. The hermit crab, a form related to the lobster, protects itself by occupying empty snail shells into which it backs in case of danger. In the Mediterranean Sea, there is frequently found on such a snail shell, a large sea anemone, which is permanently attached to it. The sea anemone belongs with the corals, jelly-fish, and hydras—a much simpler and lower class of animals than the crabs. The sea anemones are provided with numerous stinging organs that have a paralyzing effect which renders them inedible. Now the hermit crab is eaten by predaceous fish, but not when it carries around on its back the sea anemone. The sea anemone gathers its food from the water but it is stationary in habit and can secure only what the water brings to it. The hermit crab moves about from place to place thus enabling the sea anemone to secure food more easily. Such are some of the obvious reciprocal benefits.

Between true parasitism and real symbiosis there are very many social relations that cannot be properly described by either term; nor is there any sharp line of demarcation between them but an indistinct gradation from one to the other. These symbiotic and semi-symbiotic relations are not very numerous in nature and are hard to explain when the benefits are not obvious, in fact some writers believe that all of these are parasitic relations. Degeneration does not appear to be the conspicuous part of the symbiotic relations. The motive for the habit seems to be greater protection and ease in gaining a livelihood. It is conceivable that some of the relations are of the same character as in human affairs where an individual is continually being assisted without returning the compliment. Certain barnacles have a habit of burrowing into the skin of whales, the barnacle gains all of its food from the water, but is carried from place to place by the accommodating whale which can surely not be benefited in any way by these minute animals. It apparently has no way of preventing the relation. It seems a bit extreme to be always trying to figure out some utility for all of the varied relations we observe. They may be regarded as some of Nature's partly successful experiments; at any rate, they are unusual and eccentric and are given here to show that there is a wide range of relations in the social life of animals.

COMMUNITY LIFE

A colony of bees is a common expression, but the word colony has a restricted use in biology; it is applied to animals that have an actual structural connection. Many of the lower animals are colonial in habit, consisting of a hundred or more individuals of one, two, or three, or even four different kinds, all united. Each bee is free to come and go without being structurally related to the other bees in the hive. To distinguish between these two relations, the term "community" is used. The community life of the insects is varied and interesting and here the social unit is extremely modified.

Most people are familiar with the honey bee as seen in the hives, in nature they are found in some partly decayed tree. The honey bee community comprises three kinds of individuals—the queen, the drones, and the workers. The queen is the all-important personage in the hive and is called the mother queen because she lays all the eggs. The queen is the largest of the three classes and leaves the hive but once unless it is to lead off a swarm. She lives two, three, or four years, during which time she lays an incredible number of eggs. The best queens are those which lay between 2000 to 3000 eggs per day during certain times of the year. Her eggs hatch into drones, workers, or queens. The workers and queens come from the same kind of an egg, which is one of Nature's mysteries. The eggs hatch into little white larvæ in three days and it is noticeable that one larva is supplied with different food from the rest and its surroundings are enlarged spaces which the bee-keepers recognize as queen cells. The quality of the food and size of the cell are the only known factors in producing a queen instead of a worker.

The drones, a few hundred in number, are next in size and are the noisy bees that do a great amount of buzzing, but have not a sting. The drones are raised from eggs that have not been fertilized. The sole function of the drone is to act as the royal consort of the queen. The queen pairs, and as a result the drone dies after the pairing. After the pairing, the queen lays fertilized or unfertilized eggs at will. When a new queen is hatched and a swarm results, there must be a drone to pair with the new queen, otherwise they are of no service to the community. The fate of the other drones is significant. During the fall the drones are driven out of the hive and either stung to death or left to perish from hunger or exhaustion. This destruction does not necessarily occur in the fall, but may take place in the summer between the blossoming of the apple trees and that of the white clover, simply because supplies have ceased. "When in the midst of the berry season we see a worker buzzing along on the back of a drone who seems to be 'scratching gravel' to get way from the hive, we may take warning that the yield of honey is failing. I do not know that I ever saw bees sting drones, but they sometimes pretend to do so; I rather think that it is only a feint to drive them away. The poor drones at such times, after vainly trying to go back into the hive, will sometimes take wing and soar away off into the air, only to return after a time to be repulsed again, until through weakness perhaps, and want of food, he flutters hopelessly in the dust, and so submits to the fate that seems to be a part of an inexorable law of Nature and his being." (Root.)

The workers from 10,000 to 30,000 in number are sterile females that gather the honey and pollen, build the honey-comb, and feed the larvæ. The workers are smaller than the other two individuals and very active; they have a sting. It is hard to say just how long they might live if they were kept from wearing themselves out—six months or possibly a year. Their average life during the summer time is not over three months and may not be more than six weeks. "During the summer months the life of the worker bee is probably cut short by the wearing out of its wings, and we may, at the close of a warm day, find hundreds of these heavily-laden, ragged-winged veterans making their way into the hives slowly and painfully, compared with the nimble and perfect winged young bees. If we examine the ground around the apiary at nightfall we may see numbers of them hopping around on the ground, evidently recognizing their own inability to be of further use to the community. We have repeatedly picked them up and placed them in the entrance, but they usually seem bent on crawling and hopping off out of the way, where they can die without hindering the teeming rising generation." (Root.)

In the bee community there is introduced the sterile female which is in reality a sexless individual, the social unit being the queen and drone.

In this very brief survey of some of the adaptations of organisms, particularly animals in their several habits, the many structural adaptations and the whole question of color has intentionally been omitted because of lack of space. It is important to understand that these many relations represent acquired though perfectly natural habits that have reached their present high state of differentiation through a series of gradual adaptations. In seeking to explain the phenomena of parasitism and symbiosis the factors in the immediate environment are the causes to be studied. The community of the ant and bee has become so highly specialized that they could not exist if each individual pair were compelled to live apart, and the same is true of some of the parasites which live in two or more hosts like the tapeworm or the rust, when one of the hosts fails the species is unable to perpetuate its kind. While, on the other hand, there are parasites that can live attached to a host for a time and equally well when separated from it. This is the case with many of the parasitic bacteria which suggests that bacteria now non-parasitic may gain access to some animal and cause a disease new to science.

CHAPTER XV

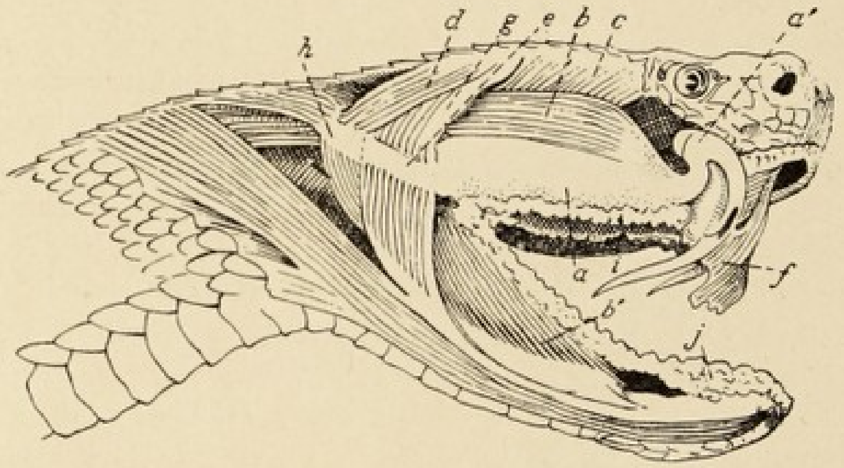
SOME BIOLOGICAL FACTORS IN DISEASE

The Role of Biology.—The skilled investigation of many men in many lands along the lines of technical research is fast revealing to us the part played by animals and plants in disease. No text-book can be up to date upon this topic for any length of time because so much that is new is continually being reported in the scientific journals. The part played by biology in these revelations is interesting and important. To biology belongs the study of the several pathogenic organisms in their relation to other organisms, in their habits and in their life history. The sources of infection, methods of carrying disease, and the fate of the disease-causing organism are strictly biological problems which are again studied in medicine because of their importance. Biology also emphasizes the fact that the so-called biological diseases have a well-recognized history associated with specific changes in the pathogenic organisms which are revealed as the disease progresses. These modern studies are more wonderful and strange than any tale of fiction and would seem to belong to the realm of the miraculous were they not abundantly substantiated by experts in all civilized lands.

The pathogenic organisms have a definite life history that must be understood in order to prevent their gaining access to plants, animals, and man. It is important to recognize at the outset that these biological diseases occur generally in nature and often with disastrous results as the frequent epidemics in insects, in fishes, in trees, in potatoes, etc., indicate. Their manner of causing disease and all of its accompanying phenomena can be as well studied in plants as in animals. The knowledge that definite plants and animals cause disease is one of the most valuable facts in our modern civilization, for it supplies us with the exact information necessary to prevent disease. There is no way of measuring the money value of a human life and yet hundreds are dying daily in the world at large from these biological, preventable diseases. Every agency should be utilized in spreading accurate information about disease and its prevention. It is impracticable in the following sections to describe all of the biological diseases and certain typical ones are selected to illustrate the general principles involved.

Rattlesnakes.—The rattlesnakes all possess a gland, located on both sides of the head and just below and behind the eye, which secretes a poison. From the anterior end of the poison gland extends a duct that opens at the base of the fang. The following account will serve to illustrate how the poison acts upon man. One of the attendants at the National Zoölogical Park was bitten on August 17 by a diamond rattler (*Crothalus adamentens*) on the middle finger of the left hand, proximal phalanx. The wound was immediately sucked and within fifteen minutes cauterized with a 1 per cent.

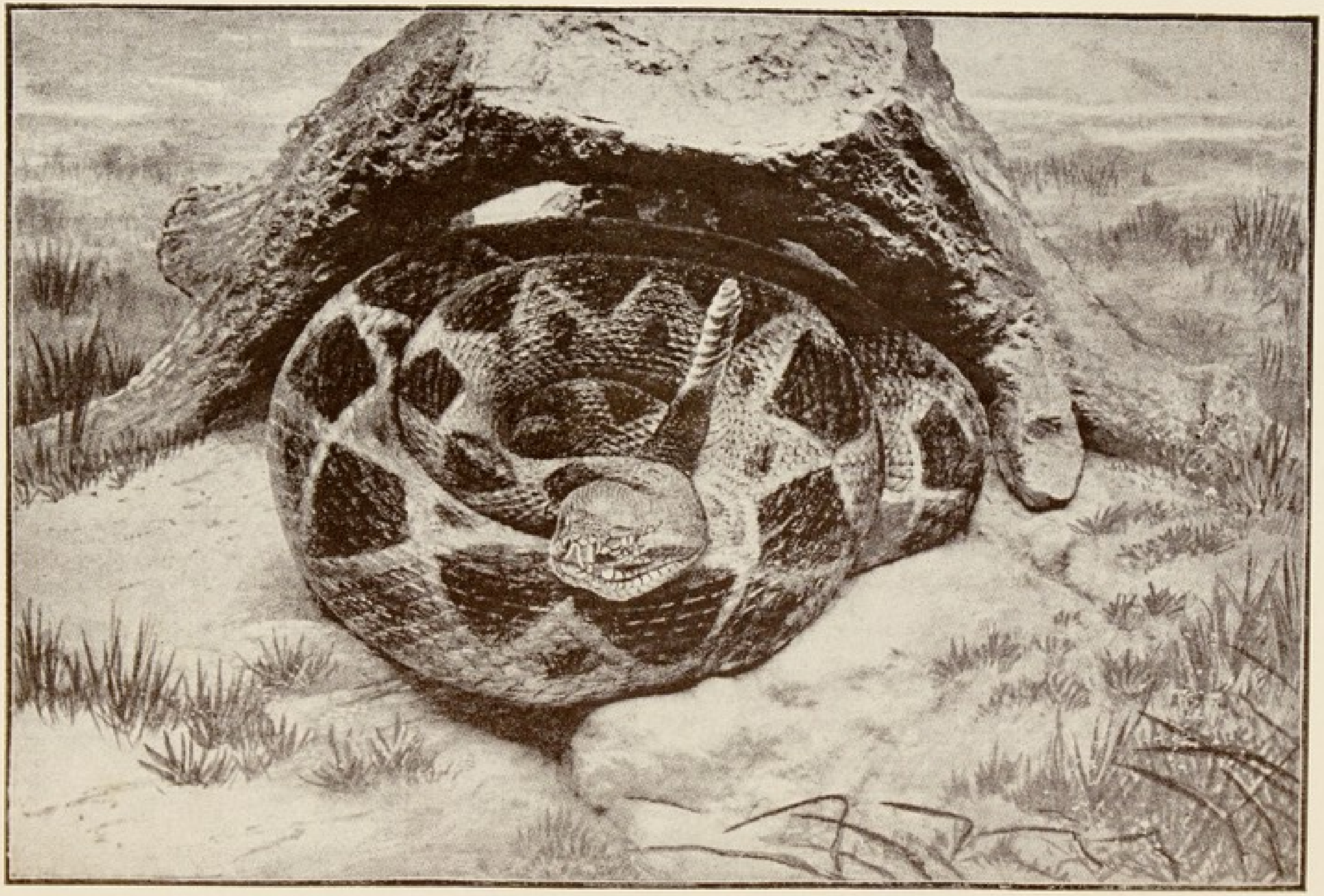
Fig. 150



Poison apparatus of rattlesnake, venom gland, and muscles. Lateral view. *a*, venom gland; *a'*, venom duct; *b*, anterior temporal muscle; *b'*, mandibular portion of same; *c*, posterior temporal muscle; *d*, digastricus muscle; *e*, posterior ligament of gland; *f*, sheath of fang; *g*, middle temporal muscle; *h*, external pterygoid muscle; *i*, maxillary salivary gland; *j*, mandibular salivary gland. (From Steineger, after Duvernoy.)

solution of potassium permanganate. He was removed to a hospital where the following changes were found to be taking place. On admission the blood examination was: red blood cells, 4,600,000; white blood cells, 14,440; hemoglobin, 95 per cent. Eighteen hours after being bitten the blood examination was: red blood cells, 4,000,000; white blood cells, 16,000; hemoglobin, 75 per cent. On the fourth day the blood count was: red blood cells, 2,800,000; white blood cells, 14,000; hemoglobin, 60 per cent. The sixth day showed the lowest condition of the blood: red cells, 2,000,000; white, 12,000, hemoglobin, 45 per cent. After this date the patient began to recover and the cells of the blood gradually returned toward the normal,

PLATE III



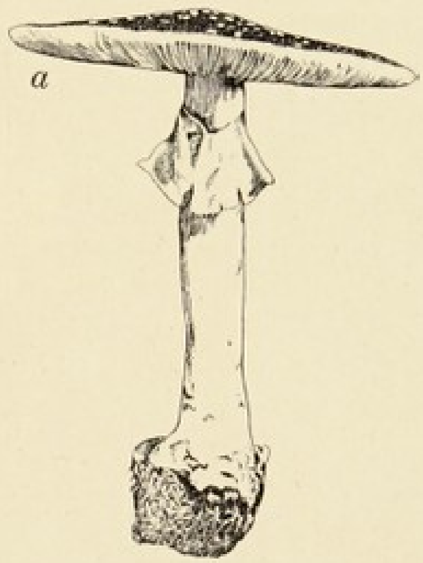
Diamond-backed Rattlesnake (*Crotalus Adamanteus*).

(From a Cast in the United States National Museum.)

although six weeks after the snake had bitten him his blood count was only: red, 3,588,000; white, 9000; hemoglobin, 87 per cent.[1]

This case serves to indicate that there is a direct relation between the loss of the red blood cells and the bite of the snake. When the rattlesnake venom is injected into the blood of other mammals a similar result obtains. The breaking down of the red blood cells (chromolysis) is only part of the process but serves to indicate the definite result that comes to certain cells of the body when they come in contact with rattlesnake venom. As is well known, the bite is fatal in about 40 per cent. of the cases. If the details of the course of the disease in man resulting from the bite of a cobra were at hand, it would be seen that the changes were of a different character and that the disease followed a regular series in which the pathogenic phenomena could be readily distinguished from those associated with the bite of a rattlesnake.

Fig. 151



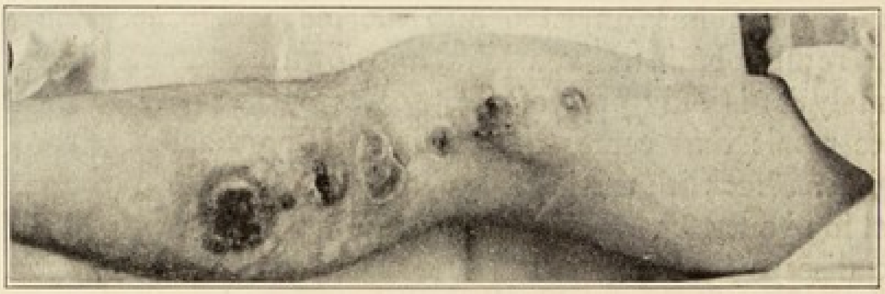
Amanita phalloides. (Rusby.)

Amanita.—Every year there are cases of mushroom poisoning which terminate fatally. In all of these serious cases the mushroom eaten is probably one of the amanita group. The general effect of the poison is to produce acute intestinal pains, a rise in the pulse and temperature often accompanied by delirium. The following is taken from Ford's recent study of the poisons in fungi: "It has been shown that the 'white' or 'deadly' *Amanita phalloides* contains a powerful hemolysin which acts upon a great variety of corpuscles, is destroyed by heating to 60° to 65° C. for half an hour and has the chemical composition of a glucoside containing C=48.03, H=6.08, N=10.83, S=1.94, O=32.22. This substance judging from its destruction by heat and its susceptibility to the action of artificial gastric juice cannot be held responsible for the symptoms seen in poisoning with the fungus in man. The species apparently owes its toxicity to the amanite-toxin.

[1] The details of the case are given by Dr. C. S. White in Jour. Amer. Med. Assoc., 1910, vol. lii.

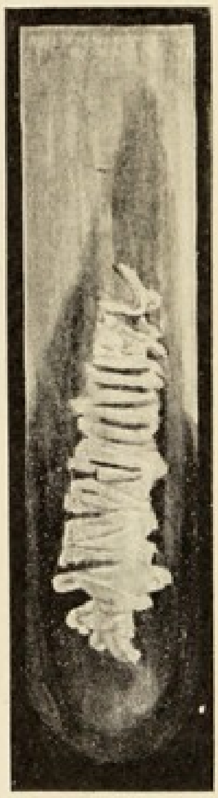
Five cubic centimeters of the extract of *Amanita phalloides* killed a guinea-pig, weighing 385 grams, over night, the same amount killed

Fig. 152



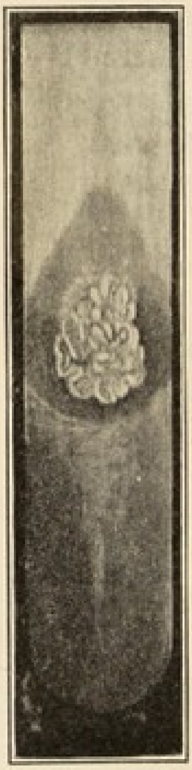
Sporotrichosis. Appearance of leg on entrance into hospital four months after initial lesion. (Hamburger.)

Fig. 153



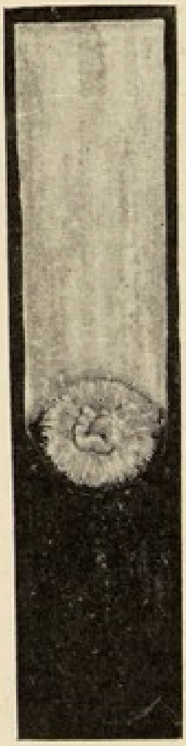
Sporotrichosis. Seven-day growth on 2 per cent. glucose agar. (Hamburger.)

Fig. 154



Sporotrichosis. Sixteen-day growth on 2 per cent. glucose agar. (Hamburger.)

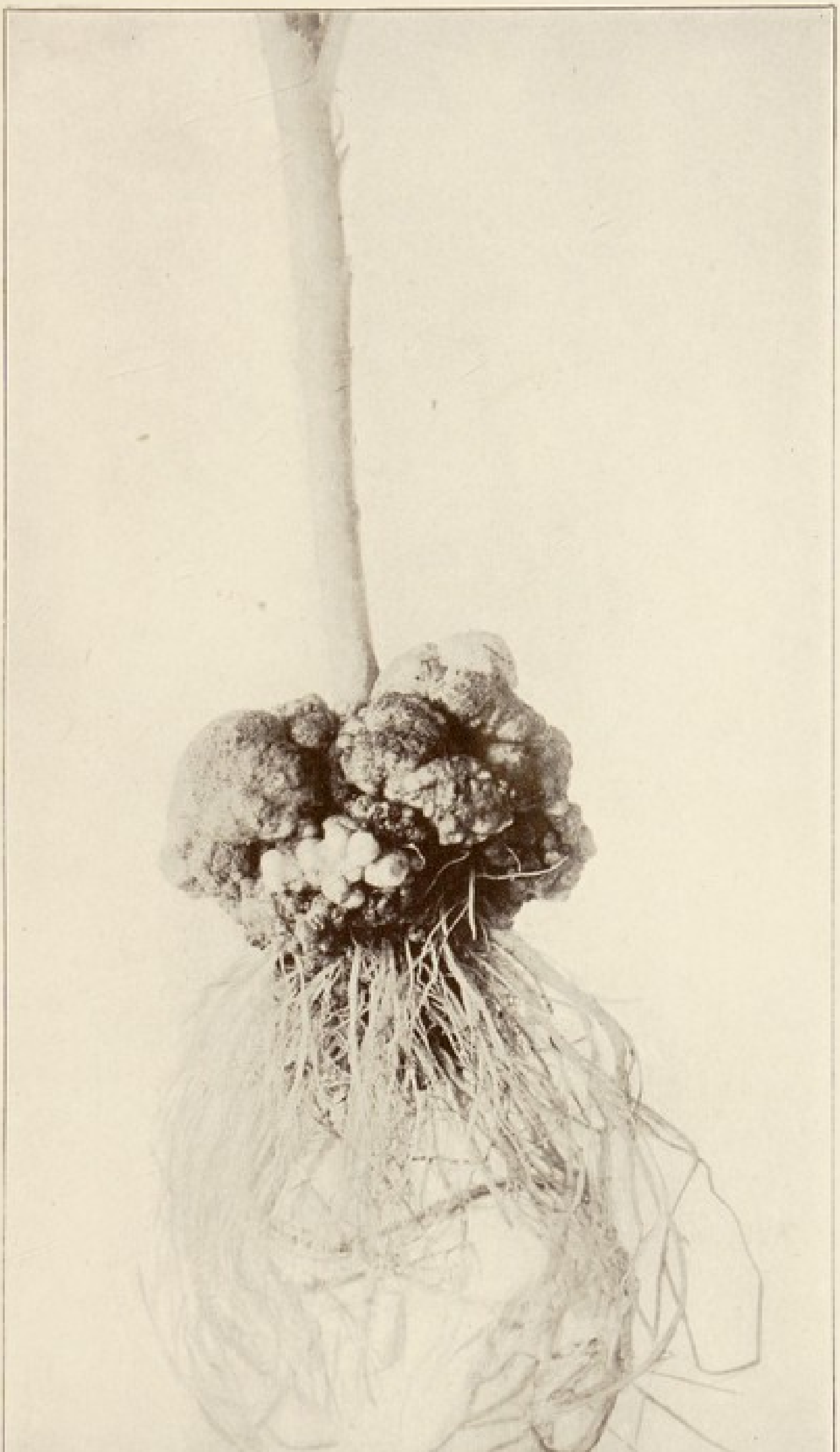
Fig. 155



Sporotrichosis. Litmus glucose agar, sixteenth day, room temperature. (Hamburger.)

another guinea-pig weighing 420 grams in four hours, and a rabbit weighing 1035 grams succumbed within eighteen hours to a dose of this character."

PLATE IV

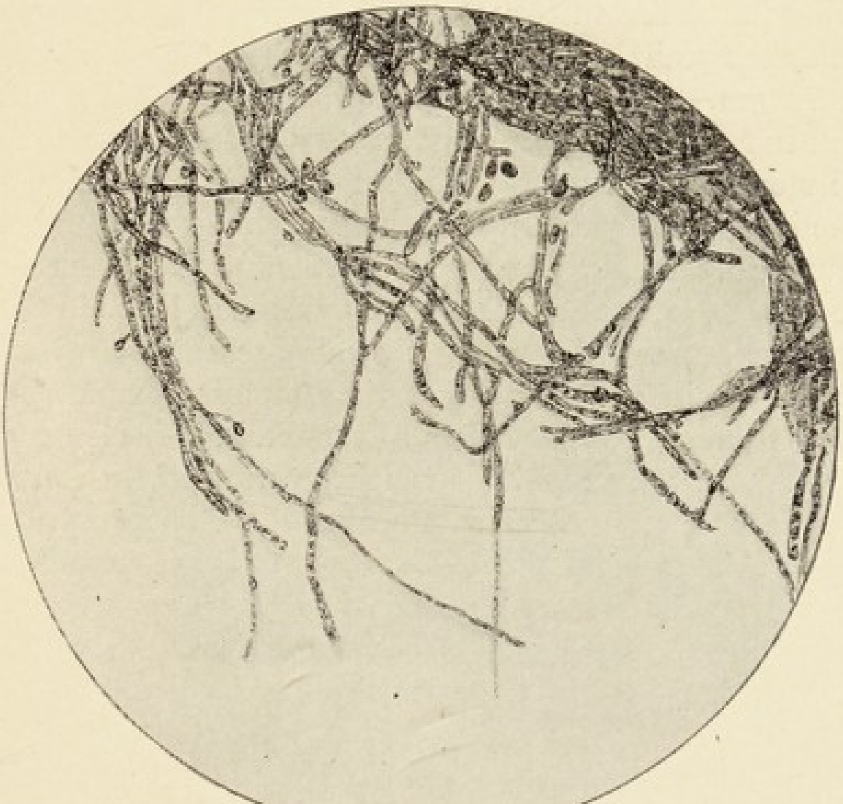


Crown Gall Occurring Naturally in Hot-house. About four-fifths natural size. (E. F. Smith.)

"The *Amanita muscaria,* known popularly as the 'yellow' or the 'fly' amanita, owes its toxicity to the crystalline substance muscarine, an ammonia derivative with the following chemical composition: $C_5H_{15}NO_3$. The muscarin extracted from this plant acts upon the nerve centres and the animal dies in convulsions. In addition to the muscarin this species contains also an hemolysin and an agglutinin, the latter acting like a glucoside."

The poison of the rattlesnake and of amanita are complex substances and already analyzed into two or more parts, and each of the components is responsible for a definite set of changes when introduced into man. In both instances the poison is a normal growth product in the organism.

Fig. 156



Sporotrichium. Four-day-old colony in plain bouillon; methylene blue; oil immersion; showing septa in mycelium. (Hamburger.)

Sporotrichosis.—This is not a common disease in man, although the authentic number of cases has increased during the last few years. The disease is described here because it illustrates so well the relation of a definite organism to a specific pathogenic condition. Small ulcers occur usually on the leg and hand and from these ulcers may be cultivated a definite plant as shown in Fig. 152. It grows exceedingly slowly when first cultivated in culture tubes. The growth of the second and third generations, however, is much faster. The organism consists of a branching mycelium with here and there spore-forming branches. When cultures of the spores are injected into white rats and guinea-pigs abscesses form in some instances; and preparations from these abscesses show the presence of similar spores. In sections of the tissue similar spores are also found.[1]

In addition to this fungus (sporotrichium) found growing in the abscesses there are a number of other moulds and yeast-like plants that act in a similar manner. For these latter the term mycosis may be given (variously named blastomycosis, oidiomycosis, saccharomycosis), and the plant can be cultivated and studied and its morphology and life history fully determined in most instances. As soon as the plant can be removed or killed the ulcers heal.

Ergot Fungus.—"The fungus which produces ergot is a member of the black fungus group, though not a very close relative to mildews. The life story of such a fungus is somewhat complex and we may illustrate by that of rye. In the summer when the youngest grains are commencing to fill, or just before that period when the grass flower opens, the spores of the ergot fungus may lodge in the flower and start to grow. The young threads are capable of attacking the growing grain and in a short time almost completely absorb the latter, forming a more or less soft, spherical, or elongated mass of mycelium, at the summit of which are formed, in convolutions of the surface, thousands of summer spores. These are accessory spore-forms. The production of these spores is accompanied by the formation of sweet saccharine fluids which are very attractive to certain insects. Visiting insects become at least partially covered by the summer spores in the sticky solution and in their visit to other flowers transfer these spores, just as they do the pollen, from flower to flower. Now it is only in the young stages of the flower that these spores can attack the grain so that rapid spread of spores is necessary and is, moreover, readily accomplished by this insect method of spore distribution. These spores are produced by the fungus for some time. Toward the time of ripening of the grain the production of summer spores ceases and the fungus commences

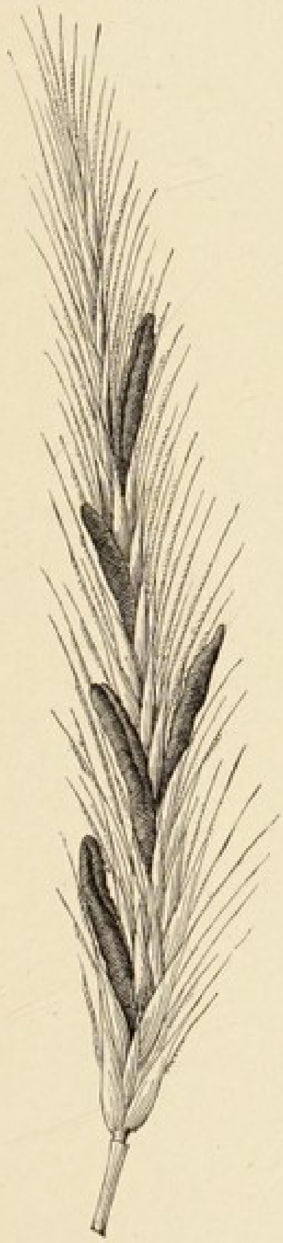
[1] Sporotrichosis in Man, by Dr. W. W. B. Hamburger, Jour. Amer. Med. Assoc., 1912, vol. lix.

PLATE V

This Plant was Inoculated December 13, 1906, and Photographed July 10, 1907. One Branch Killed.
(E. F. Smith.)

to pack up reserve nutrition in its threads. These are now compacted together in a very solid mass the exterior of which turns violet black. The whole structure becomes a storage organ or sclerotium, and often requires a rest period before it will develop further. In

Fig. 157



Ergotized rye. (Maisch.)

Fig. 158

Ergota. (Maisch.)

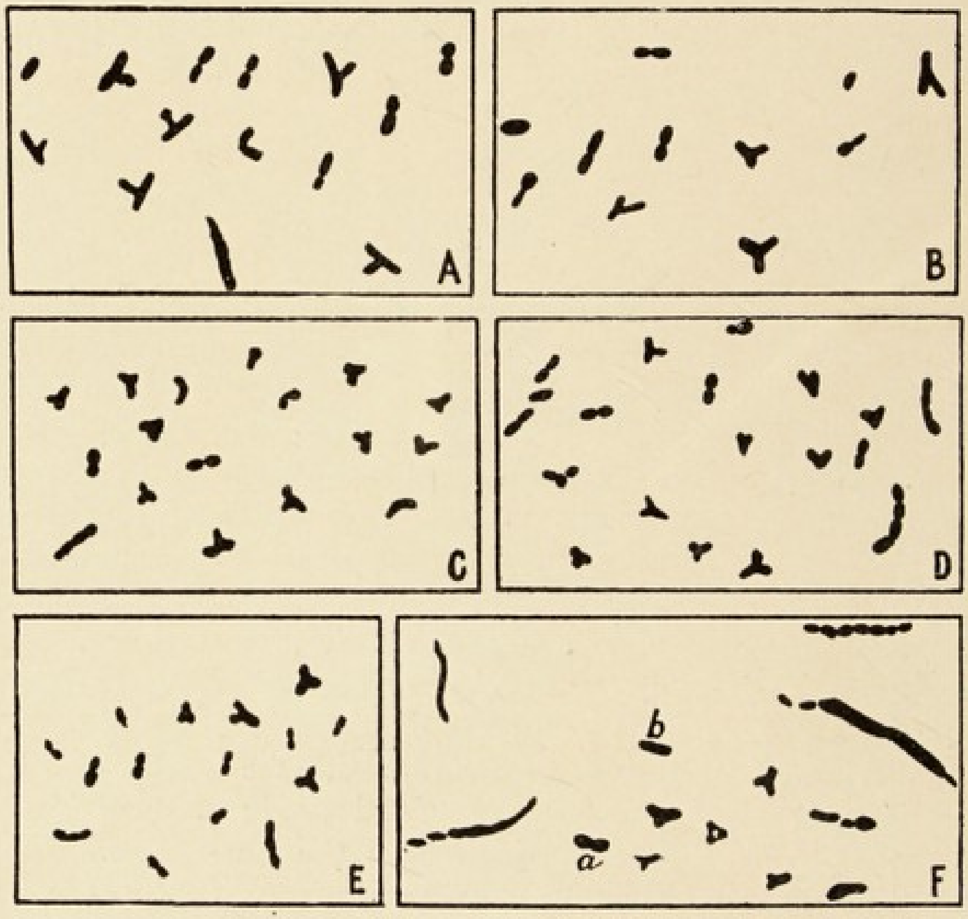
this sclerotium nutrient material is found in the form of fungus starch and oils. Certain violent poisons are also found in them and are extensively used in medicine, for this storage organ is known in pharmacy as the drug 'ergot.' Of just what use to the fungus these poisonous compounds are is not quite clear. Possibly they tend to prevent the consumption of strongly ergotized grains, thus avoiding destruction by feeding animals." (Freeman).

The further details of the life history are briefly as follows: In the spring the ergot begins to grow and produces small blackish bodies which bear the sac spores. Due to stored-up material in the sclerotium a large number of spores are produced. These spores must now be carried to a flower where they can begin to grow and repeat the life story. This fungus is common on grasses, wheat, barley, rye, etc.

Ergot serves to introduce another factor in the study of disease, namely, a complicated life history and one in which insects act as innocent carriers of the summer spores from plant to plant. The spores do no harm to the insects.

Crown Gall.—Crown gall is a disease which occurs on a variety of plants and any part of root or shoot is liable to attack. It consists in an irregular growth which frequently becomes larger than the root or shoot upon which it occurs. In this growing mass of cells the conducting tissues are imperfectly developed. The way that the cells grow and their manner of dividing tend to place this disease quite apart from the usual diseases in plants, locating it in the category of the true tumors; it is believed by Smith that the conditions are similar to animal tumors.[1]

Fig. 159



Bacterium tumefaciens. (E. F. Smith.)

The cause of this disease has been one of the unsolved problems until the recent work of Smith and others. The successive steps employed in demonstrating that crown gall is due to a definite

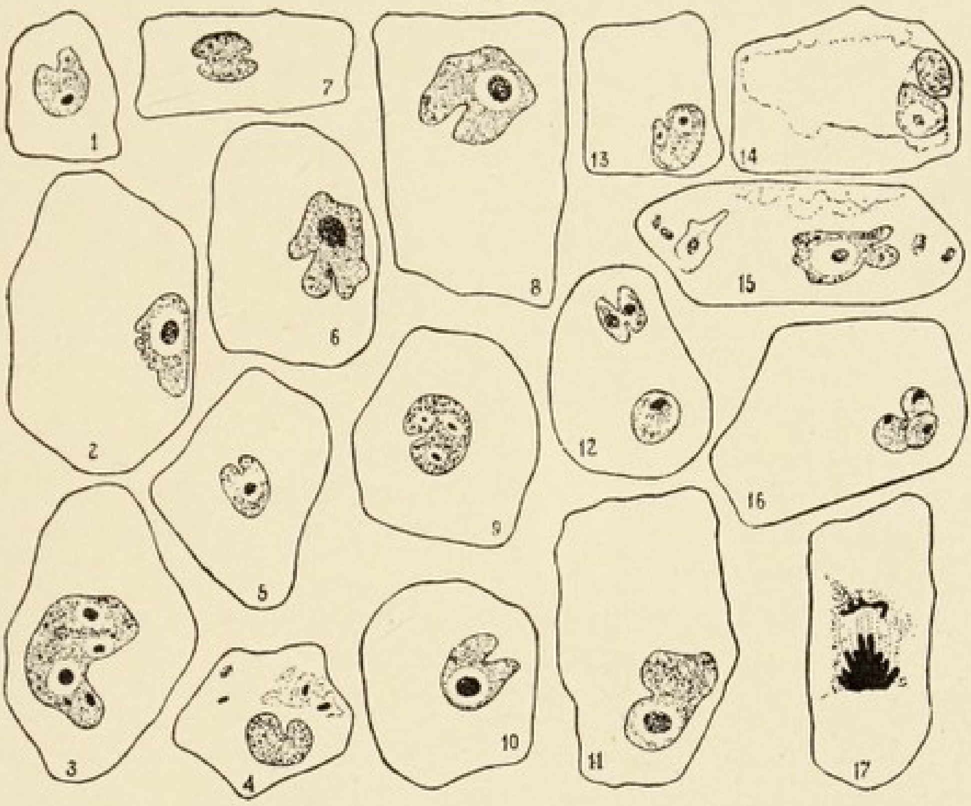
[1] Smith, Brown, and Townsend, Crown Gall of Plants: Its Cause and Remedy, Bureau Plant Industry—Bull. No. 213; Smith, Brown, and McCulloch, The Structure and Development of Crown Gall: A Plant Cancer. Bureau Plant Industry, Bull. No. 255.

PLATE VI

A Natural Infection of Crown Gall in the Hot-house, which has probably resulted in the transfer of the germs by way of the gardener's hose in watering. (E. F. Smith.)

organism were the following: Galls were crushed in beef broth, from which agar plate cultures were made, which were kept at temperatures varying from 20° to 30° C. The galls were thoroughly cleaned and modern antiseptic methods used. The second step was the finding of a definite organism, to which the name *Bacterium tumefaciens* was given, growing on the agar-culture plates (Fig. 159).

Fig. 160



Nuclear divisions in crown gall. Nos. 1 to 16, cells showing stages of amitotic division; No. 17, mitotic division in which more chromosomes have passed to one pole than to the other. Material fixed in Flemming and stained with Heidenhain's iron hematoxylin. (E. F. Smith.)

The third step was to demonstrate that the bacteria isolated on the agar plates would cause a similar growth when introduced into the tissues of a healthy plant. On June 1, inoculations were made into the stem of young healthy daisy plants growing in the pathological green-house. On June 18 a distinct elevation was visible at each point where an inoculation had been made.

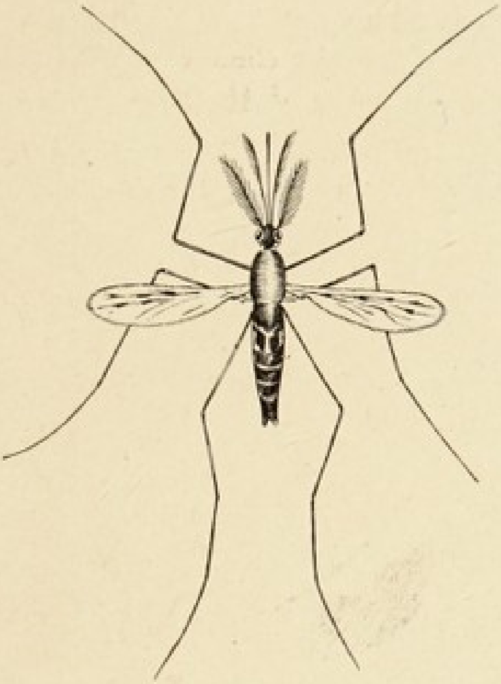
The fourth step was the study of these new galls and the finding of the same organisms present. The infectious nature of these organisms was proved by inoculating healthy plants which in turn produced galls. This method of conclusively proving that a given disease was caused by a given organism was formulated by Koch, The bacteria causing this disease are located inside the cells and it is the "stimulus of their presence which causes the cell to divide abnormally by throwing it out of balance." After the crown-gall tumor has been grown another series of changes begins. It seems that the soft tissues cannot be adequately nourished beyond a certain limit and decay sets in. "A variety of saprophytic bacteria and fungi take part in disintegrating the overgrown tissues. Among these saphrophytic bacteria there are several white forms closely resembling the gall organism as grown on agar poured plates, dendritic white forms, green fluorescent species, yellow species, orange species, pink species, etc."

This disease serves to illustrate the method of determining the exact cause of a biological disease. The growth of the cells in crown gall is believed to be due to some stimulus produced by the bacteria as they live naturally, although as parasites within the cells. When the original disease reaches its limit a number of disintegrating bacteria begin to live upon this abnormal growth, with the result that decay sets in and parts slough off causing an open wound. The organisms which bring about all of these undesirable results are definite living things which have a specific structure and life history.

Malaria.—When this disease was first recognized it was thought to be associated with bad air and was so named, malaria. In 1881 a French military doctor located in Algiers, Dr. Laveran, discovered in the blood of some malarial patients a new organism which he declared to be the cause of the disease. It was more than fifteen years after this discovery before definite information was available as to the source of this parasite in the human blood. The name *Plasmodium malaria* was given to this organism because of its supposed resemblance to some of the plasmodia-forming fungi. Authorities differ as to the exact number of malarial pasasites but they all belong to the animal kingdom and are protozoa, class sporozoa, order hemosporidia (see page 138).

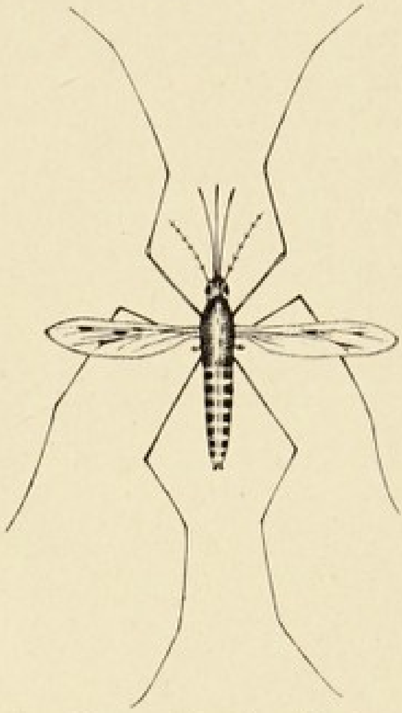
The malarial parasite is not able to complete its life history in the one animal (the frog, reptile, bird, or mammal) in which it first occurs. The malarial plasmodium passes through a series of changes in the human blood as follows: The parasite penetrates a red blood corpuscle where it increases in size until it nearly fills the blood cell. The time that it remains in the cell depends upon the kind of parasite whether it be a one-day, a three-day, or a four-day form. At first the parasites are not very numerous, but after a few weeks their number is very great. As they all belong to the same original brood, they mature in the blood cells at the same time and are liberated from the blood cells at the same time.

Fig. 161



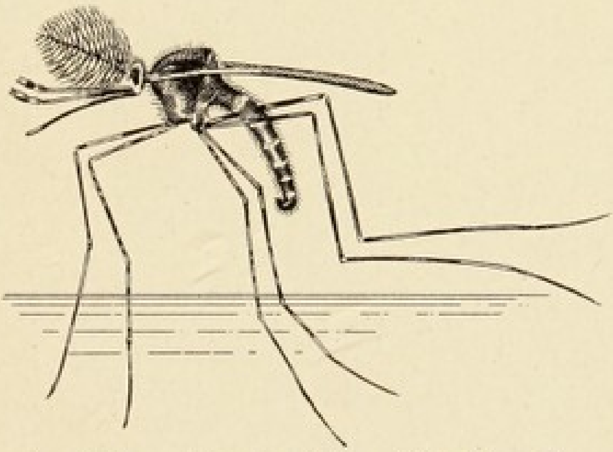
Anopheles maculipennis. Male. (Harrington.)

Fig. 162



Anopheles maculipennis. Female. (Harrington.)

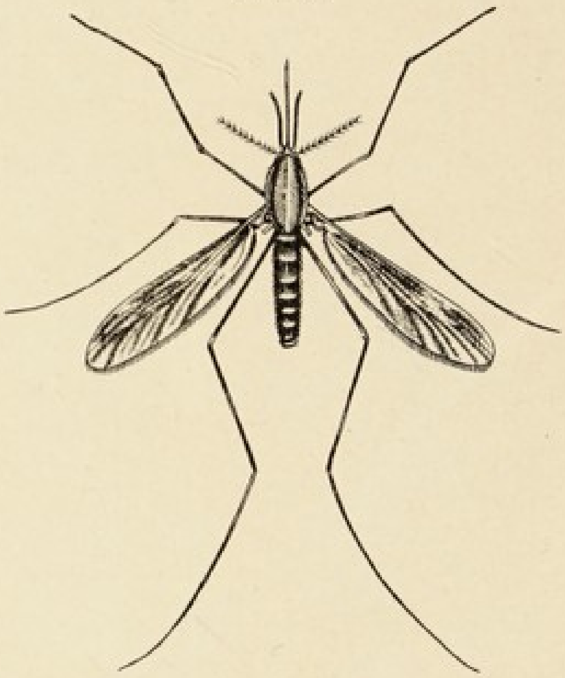
Fig. 163



Anopheles punctipennis. Male. (After Howard.)
Figs. 161 to 166, carriers of malaria.

The fever accompanying this disease coincides with the liberation of a new swarm of parasites. The waste products of the parasite metabolism are also set free at the same time and assist in setting up disturbances in the body. After a time the parasites develop into two forms which are the sexual phases, the macrogametocytes and the microgametocytes. These cells do not fuse while the parasite remains in the human blood but in the stomach of the anopheles mosquito. The fertilized cell makes its way into the lining epithelium of the intestine and comes to rest in the submucosa. Here it undergoes a series of divisions and ultimately gives rise to a stage known as a sporozoite. Some of these sporozoites make their way into the salivary glands and thence into the proboscis of the insect, from which they escape into the blood. The non-sexual forms of the parasite which are drawn into the stomach of the anopheles mosquito

Fig. 164



Anopheles punctipennis. Female. (After Howard.)

are destroyed. Should a culex mosquito suck up the blood of a malarial patient all of the parasites are digested. And when an anopheles mosquito sucks the blood of a bird in which the organism *Plasmodium præcox,* causing æstivo-autumnal fever, occurs the parasites are all digested.

Malaria is a disease that is distributed all over the United States and especially in the South. It can occur only through the patients being bitten by an anopheles mosquito which has the plasmodium malaria in its salivary glands. It is a serious disease in some sections, and in 1900, 14,909 persons distributed throughout the United States died from it. There is no way of estimating the number

PLATE VII

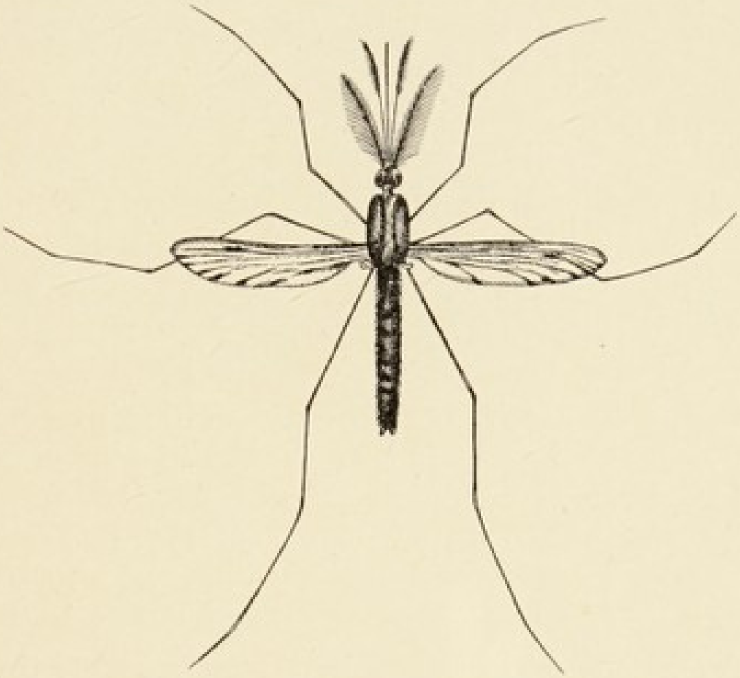
Plant Inoculated November 26, 1907, and Photographed
March 8, 1908. (E. F. Smith.)

PLATE VIII

Tumor Strands in Stem of Daisy. (E. F. Smith.)

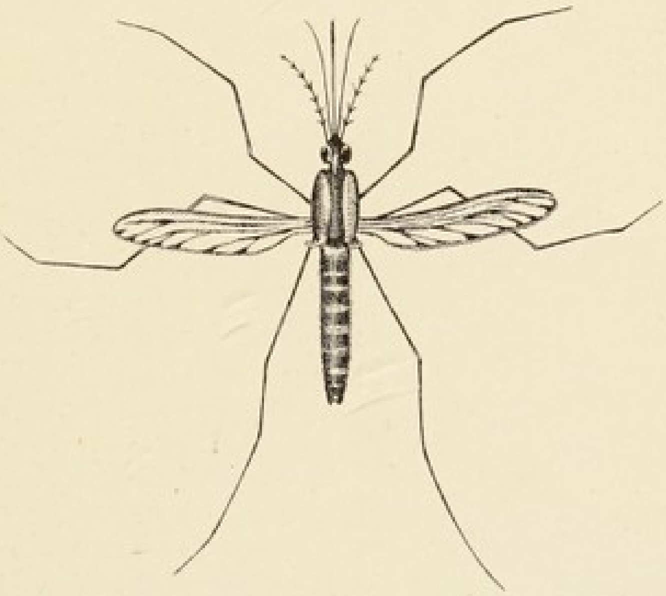
that were incapacitated from working because of this disease. The writings of many of the Roman authors contain references to

Fig. 165



Anopheles crucians. Male. (Harrington.)

Fig. 166



Anopheles crucians. Female. (Harrington.)

destructive epidemics of malaria and the efforts to drain the deadly Campagna date back for many years. The first capital of Alabama, St. Stephens, which in 1810 was a thriving town, was literally wiped out of existence because of the prevalence of malaria. The present sanitary knowledge of malaria makes it entirely safe to live anywhere in the world if one simply protects himself from the bites of the anopheles mosquito by keeping behind a screen (19 meshes to the inch) after dark.

The Bacterial Diseases.—The several diseases (typhoid fever, tuberculosis, diphtheria, colds, pneumonia, gonorrhea, leprosy, tetanus, etc.) caused by some specific bacterium may be discussed under one heading in explaining their biological relations. Each disease has its own marked symptoms and recognizable germ, but so far as their biology is concerned, all are similar. The bacteria gain access to our bodies and live parasitically, during which time the disease develops. The bacteria grow and multiply and carry on their own metabolism. The result of this normal activity on their part is the production of poisons which disturb the cells of the human body, just what cells are interfered with depends upon the organism. Each disease passes through several stages or cycles. The first is termed the incubation period and is the time that elapses between the entrance of the infection into the body and the day when the earliest symptoms appear. This idea of a period of incubation is well illustrated in the following table:

Disease with Short Incubation

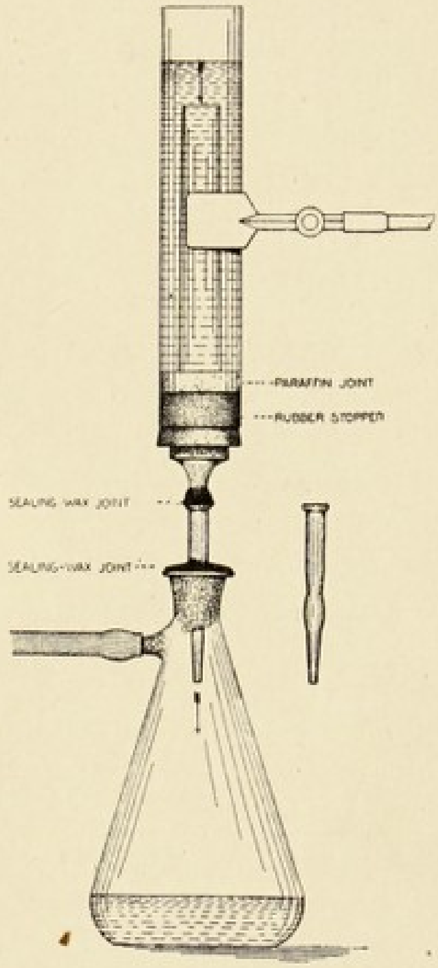
	Limits.	Usual time.
Diphtheria	2 to 7 days	2 days
Scarlet fever	1 to 8 days	3 to 4 days
Influenza	1 to 4 days	2 days
Erysipelas	3 to 7 days	4 to 5 days

Disease with Long Incubation

	Limits.	Usual periods.
Typhus fever	7 to 14 days	12 days
Typhoid fever	7 to 21 days	about 14 days
Chickenpox	10 to 15 days	about 14 days
Smallpox	9 to 15 days	generally 11 or 12 days
Measles	7 to 18 days	generally 14 days
German measles	12 to 21 days	about 14 days
Mumps	14 to 21 days	about 16 days
Whooping cough	7 to 14 days	about 10 days

The next stage is sometimes called termination period, and there are various ways in which the disease comes to a close. The steady course may end abruptly, as in typhoid fever, and convalescence set in at once, or the decline may be very gradual, and it is difficult to say just when it stops. The last stage comprises the changes occurring in the return to ordinary health and is termed convalescence. Each bacterial organism living in this parasitic relation shows certain peculiarities as does the host, so that the conditions in any two cases are never exactly the same. The changes which the bacteria cause in the cells and tissues are likewise varied, so that general statements must be made; in one case ulcers appear, in another abscesses are formed, or certain glands are swollen, etc. In the study of the bacterial diseases great care has been exercised to definitely isolate the specific germ that is the cause of the disease and work out its life history and habits, as a result one can learn how to avoid infection by such germs. The number of persons dying annually from the bacterial diseases is very large, as one soon realizes from a study of the reports from any State Board of Health, but he also gains from such study the further important fact that all of these diseases are preventable. Whether the sanitary conditions of civilized nations will ever become so perfect as to prevent any considerable number of the bacterial diseases is a question, but it is the purpose of those who understand the wastefulness that comes from sickness and death due to these diseases to try to greatly reduce their number. The greatest work for medicine in the future is to be the prevention of disease instead of its cure.

Fig. 167



Chamberland filter. The central structure is an unglazed porcelain cylinder, through which the fluid is drawn by suction and filtered.

The Filterable Viruses.—At present there are some thirty diseases of human, plant, and animal life which have been demonstrated to be due to organisms that can pass through a Berkefeld or Chamberland filter; with the highest powers of the microscope they are invisible. Of the diseases which affect man the following may be

FIG. 168

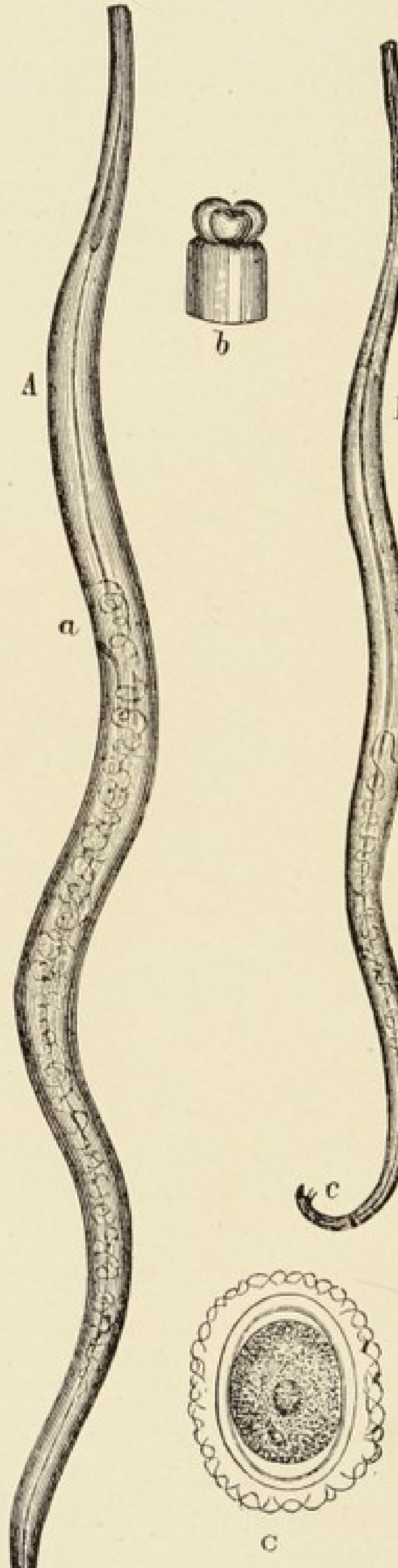


FIG. 169

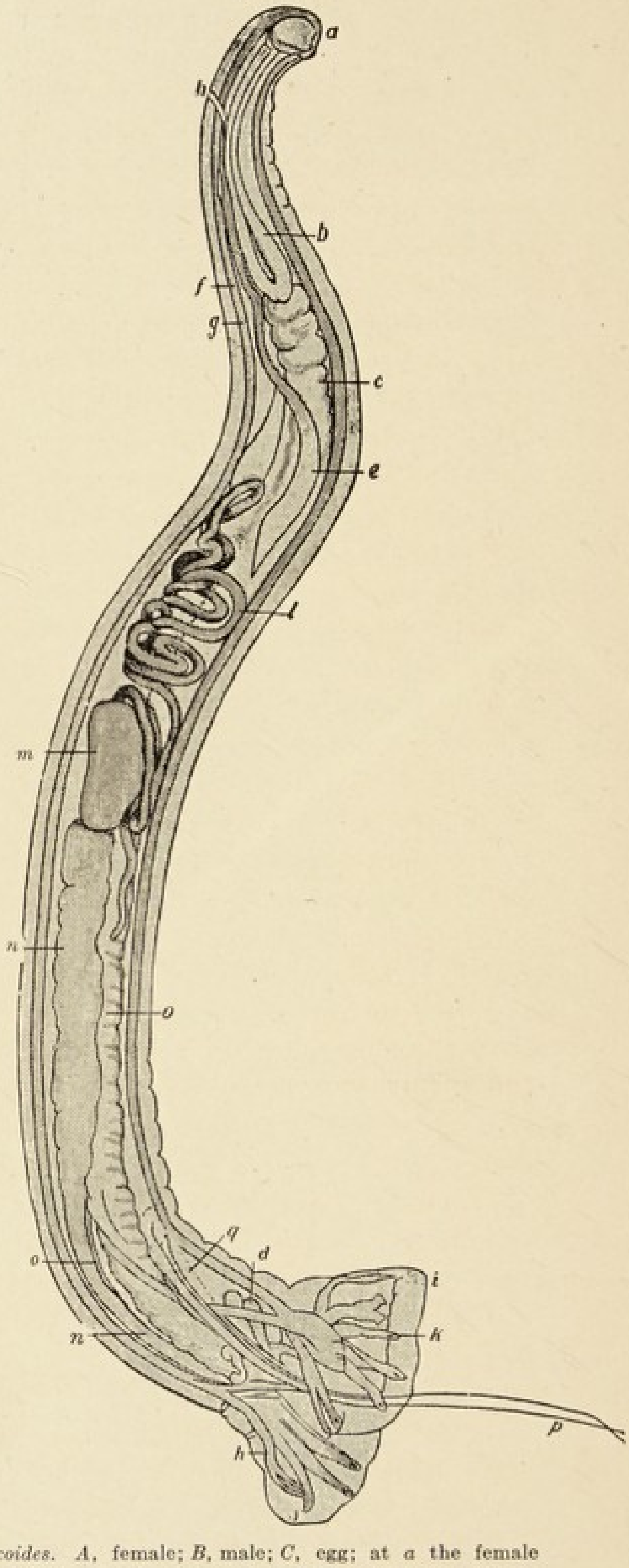


FIG. 168.—*Ascaris lumbricoides.* *A*, female; *B*, male; *C*, egg; at *a* the female genital opening; *c*, the male spicules; *b*, the enlarged cephalic extremity, with its three lips. (After Perlo, from Ziegler.)

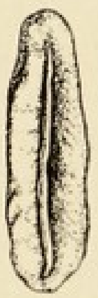
FIG. 169.—Male of *Anchylostoma duodenale.* *a*, head; *b*, esophagus; *c*, gut; *d*, anal glands; *e*, cervical glands *f*, skin; *g*, muscular layer; *h*, excretory pore; *i*, trilobed bursa; *k*, ribs of bursa; *l*, seminal duct; *m*, vesicula seminalis; *n*, ductus ejaculatorius; *o*, its groove; *p*, penis; *q*, penile sheath. × 20. (After Schulthess, from Ziegler.)

mentioned: Foot-and-mouth disease, rabies, vaccinia, smallpox, yellow fever, dengue fever, trachoma, poliomyelitis, typhus fever, and measles and scarlet fever. In most of these diseases the unknown germ is transmitted by some intermediate host, such as mosquito, body louse, or house fly. In the next few years much that is new will be added to our knowledge of this group of diseases.

Hookworms, Tapeworms, and Others.—There are a number of highly developed animals that live as parasites mostly within the digestive canal in man and other animals. These are the well-known thread-worms, hookworms, tapeworms, and others. Their chief harm consists in absorbing the nourishment taken by the host before it leaves the digestive canal and in the absorption of blood. The food being ready at hand in sufficient quantity, they have but to grow and reproduce until in some cases they become very numerous. It is not practical to make many general statements concerning this group of diseases because each animal has its own life history and mode of entering the body. Some, like the tapeworm, have a complicated life history as already shown on page 173; while others, like the hookworm, readily pass from man to man without an intermediate host. Hookworm is an ancient and world-wide disease that belts the earth in a zone about 36 north to 30 south parallel. In some parts of this district, like Samoa, 70 per cent. of the population, in southern China 75 per cent., in India from 60 to 80 per cent., in Dutch Guiana 90 per cent. are found to harbor hookworms. The economic loss from a disease so widespread is enormous. A physically sound coffee-picker in Porto Rico picks 500 to 600 measures a day; the anemic picker averages from 100 to 250 measures. The effects of this disease in stemming the progress of civilization in China, India, Egypt, and other countries cannot be measured. The practical aspect of the question comes in determining the admission of immigrants from hookworm countries. In 1911 a shipload of Indian coolies landed at San Francisco and when examined 90 per cent. were found to be infected. A low class of immigrants with their lack of sanitary knowledge become a centre from which such diseases spread. Dr. C. W. Stiles, the great authority on this disease, believes that the sanitary privy in the non-sewered districts of the Gulf-Atlantic states and the wearing of shoes are the most important measures in preventing the hookworm disease.

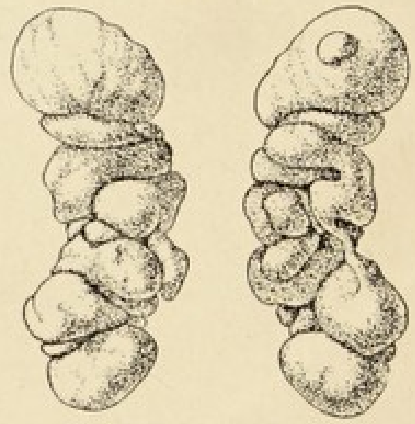
Animal Tumors.—Just how the various abnormal growths so frequently found in all of the higher animals are to be explained remains to be discovered. The recent studies on crown gall suggest that the cause may be due to microörganisms which our present technique does not reveal. This suggestion has much force in it when it is remembered that there are several diseases due to the so-called filterable viruses. These tumor-like growths are found in all of the vertebrates. A characteristic instance is shown in the kidney of the frog. This organ is usually regular in outline and of a dark red color. It is about 14 mm. long and 4 mm. wide. The

Fig. 170



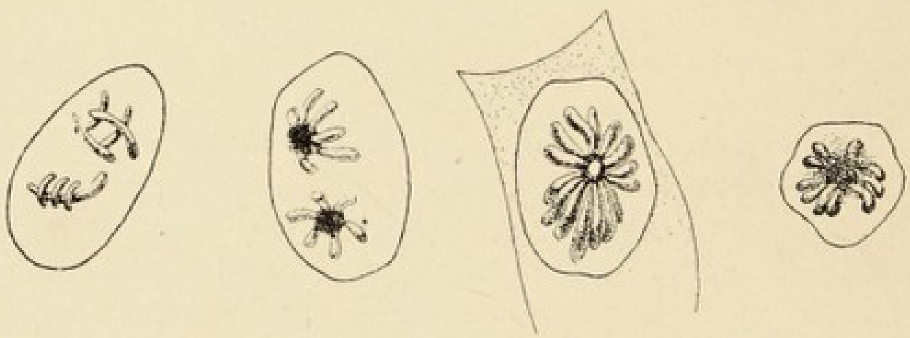
A normal sized kidney in the frog (× 2x) showing the normal adrenal.

Fig. 171



The dorsal and ventral view of the right kidney of the frog having the adrenal tumor.[1] × 2x.

Fig. 172



Nuclei showing mitosis characteristic of the adrenal tumor in the kidney of the frog.

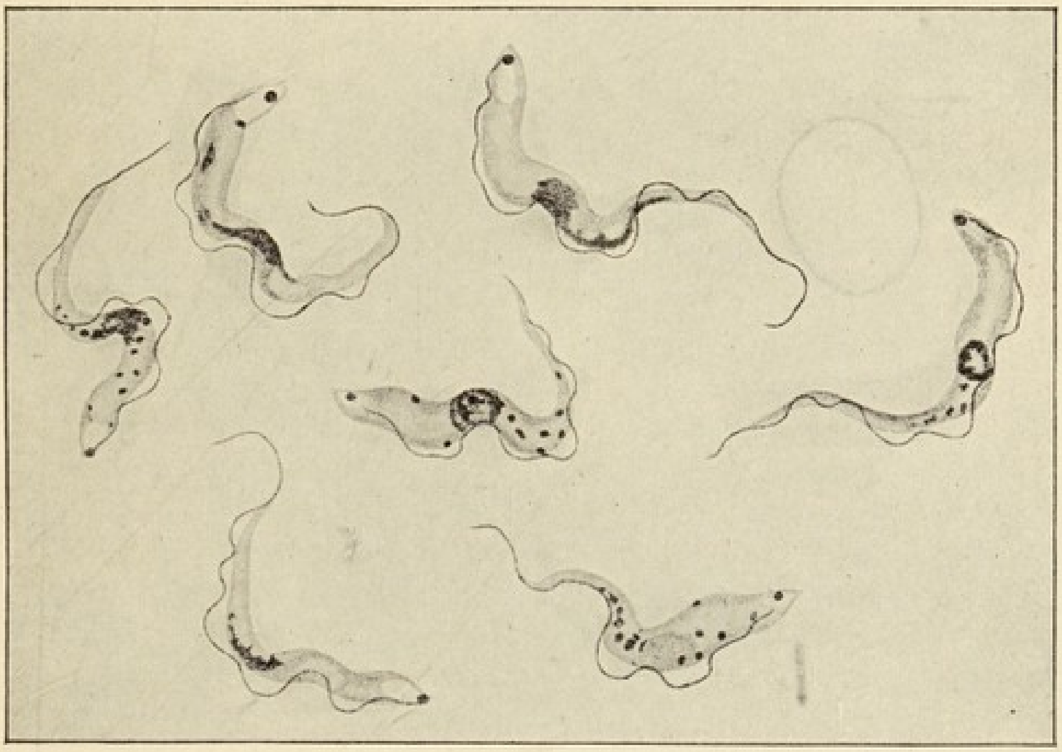
kidneys shown in Fig. 171 were 21 mm. long and 8 mm. wide, and irregular in outline. The color of the fresh diseased kidney was whitish. Each kidney has a large number of lobes. The tumor growth is so extensive that the original kidney is revealed only in blotches and the ureter is carried around to the inner edge instead of being on the outer edge of the kidney. The cells were in active stages of division and showed the usual atypical forms. The conditions in the frog are similar to those that are often found in human

[1] Adrenal Tumors in Kidney of the Frog, Anat. Auz., 1905, Bd. xxvi, No. 24.

adrenal tumors. It is greatly to be hoped that these strange abnormal growths in man and other vertebrates will finally be shown to be due to microörganisms, for then science can probably tell us how to prevent them.

Disease Carriers.—The part played by biology in helping to solve the nature of disease and of the various organisms that infect the body has been great, but biologists found an equally fertile field for study in unravelling the manner in which disease was carried from the sick to the well. The recognition that definite living organisms are responsible for the transmission of disease has revolutionized the methods employed in fighting the further spread of many of

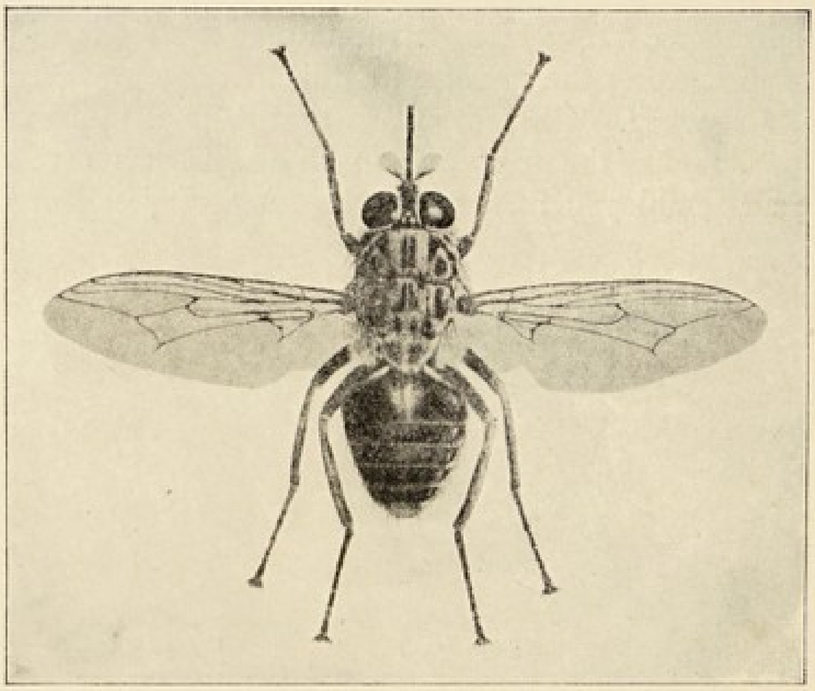
Fig. 173



Trypanosomes (*T. gambiense*) from the blood in sleeping sickness. × 2000. (Bruce.)

the infectious diseases. The term carrier is given to animals or persons who apparently in good health harbor and spread disease germs. The fact that a man appears well and yet may be spreading disease is a new idea in preventive medicine. This in no way eliminates the old idea that contact with the sick furnishes a means of transmission of disease but rather adds another source of infection. During the convalescence of a patient it is to be expected that some germs will be found but their persistence in a person after he is well or their existence in a person who has never had the disease is difficult to explain. Among men there are (1) convalescent, (2) chronic, and

Fig. 174



Glossina palpalis (×3¾), the carrier of the trypanosome of sleeping sickness. (Bruce.)

Fig. 175

Stomoxys calcitrans, the probable carrier of poliomyelitis. × 3 diameters. (Edelmann.)

(3) healthy carriers. Diphtheria and typhoid fever are two common diseases in connection with which carriers are found. The spread of epidemics is now frequently traced to a person who believed himself to be perfectly free from such germs. The elimination of the sporadic

PLATE IX

Fig. 1

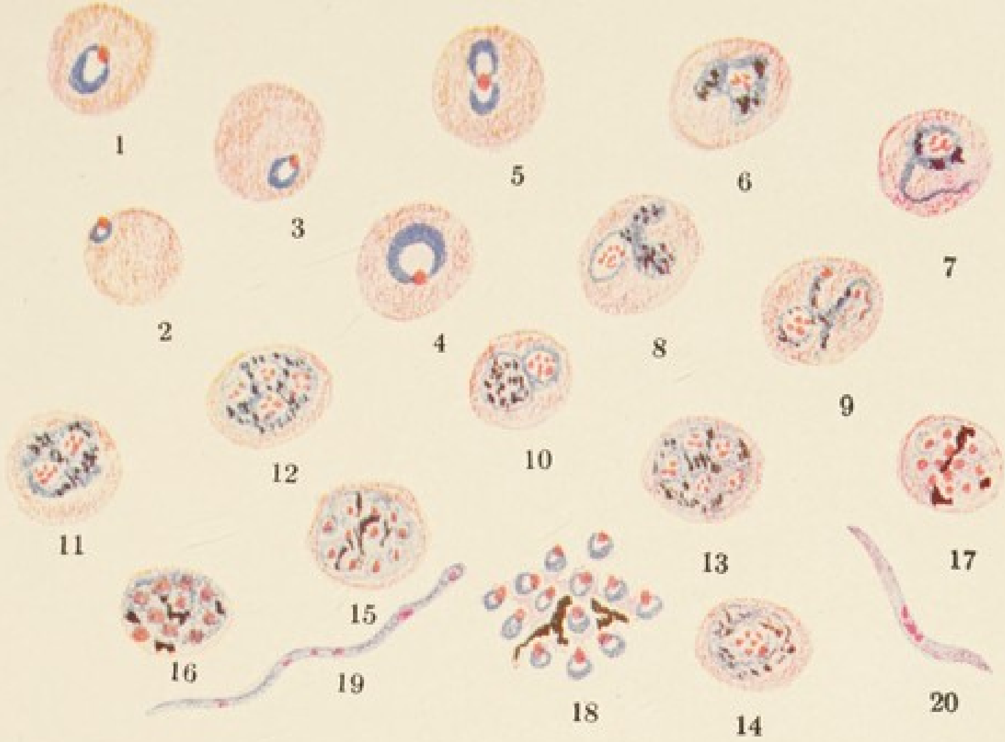
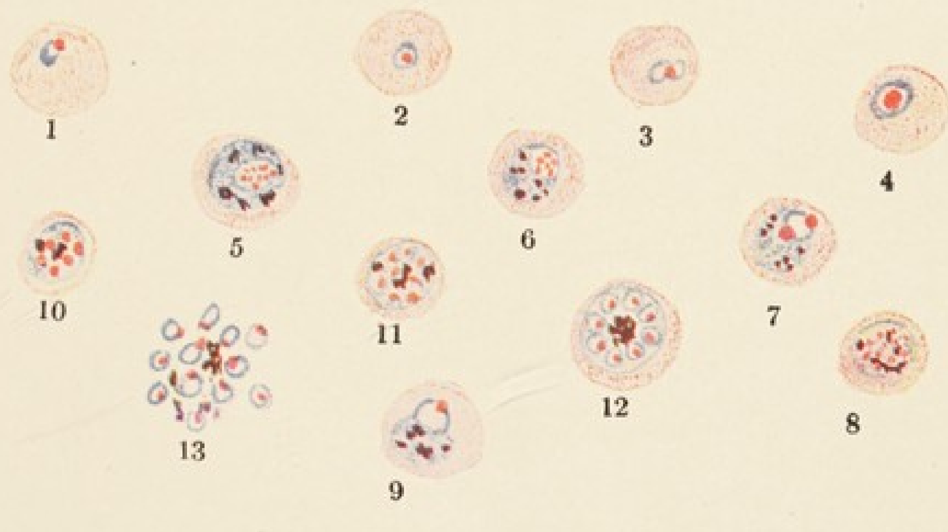


Fig. 2



CHARLES F. CRAIG, DEL.

Fig. 1.—Tertian Malarial Plasmodium. Stained by Oliver's Modification of Wright's Stain.

1 to 4. Ring forms of tertian parasite.
5. Ring form. (Conjugation form of Ewing.)
6 to 10. Pigmented organisms.
11 to 14. Nearly full-grown forms, showing diffusion of the chromatin.
15 to 17. Segmenting forms within red corpuscle.
18. Segmenting forms after destruction of red corpuscle.
19. Microgamete.
20. Sporozoite.

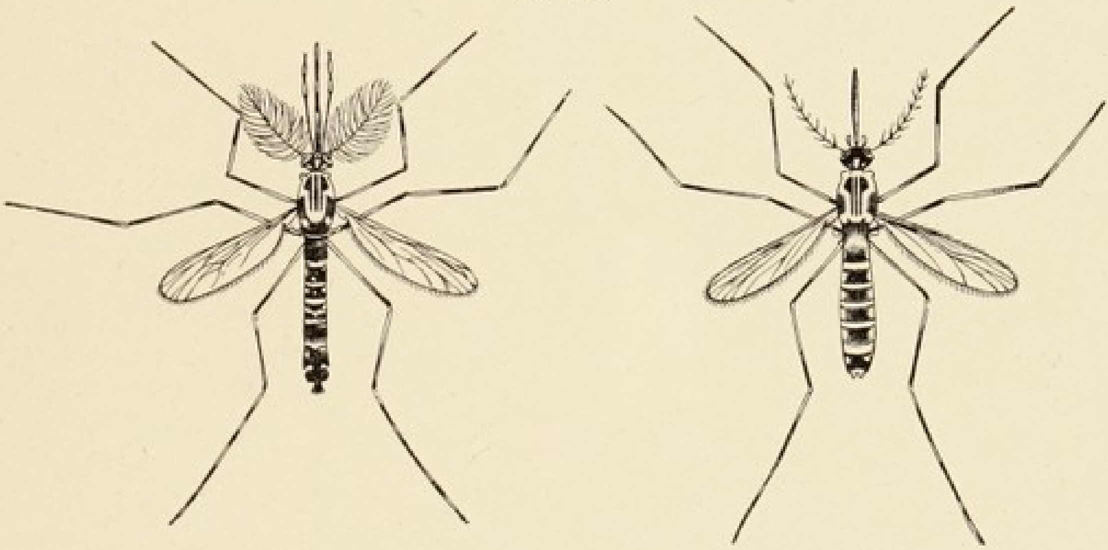
Fig. 2.—Quartan Malarial Plasmodium. Stained by Oliver's Modification of Wright's Stain.

1 to 4. Ring forms of quartan parasite.
5, 6, 7, 8, 9. Pigmented parasites.
10 to 12. Segmenting forms of quartan parasite.
13. Segmenting stage after destruction of red corpuscle.

Note.—Chromatin of nucleus stained red; protoplasm stained blue; vesicular portion of nucleus unstained.

cases of diphtheria in certain schools is now readily accomplished by simply locating the diphtheria carriers in the school. Malta fever furnishes an interesting illustration of the principles involved. This disease is due to *Micrococcus melitensis*. The goat is really a chronic carrier of these bacteria. When the goats on the Island of Malta were examined by the British Commission, fully 50 per cent. gave a test which showed that they were harboring the germs and 10 per cent. were actually secreting the bacteria in their milk. All that was necessary was to boil the goat's milk or avoid using it to put a stop to Malta fever. In a similar way, then, milk tuberculosis is caused.

Fig. 176

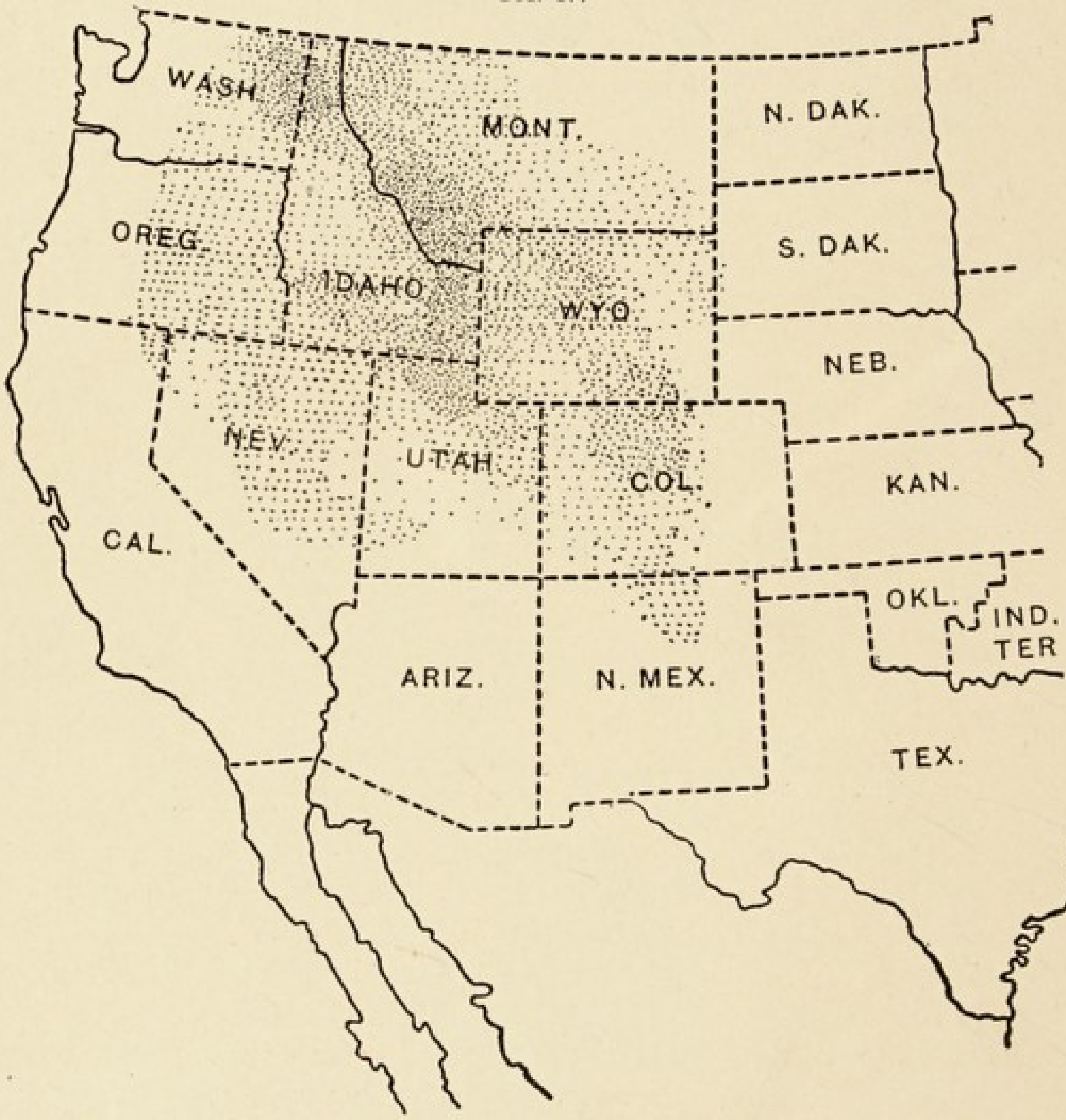


A *B*

Stegomyia fasciata, carrier of yellow fever. *A*, male; *B*, female. (After Howard.)

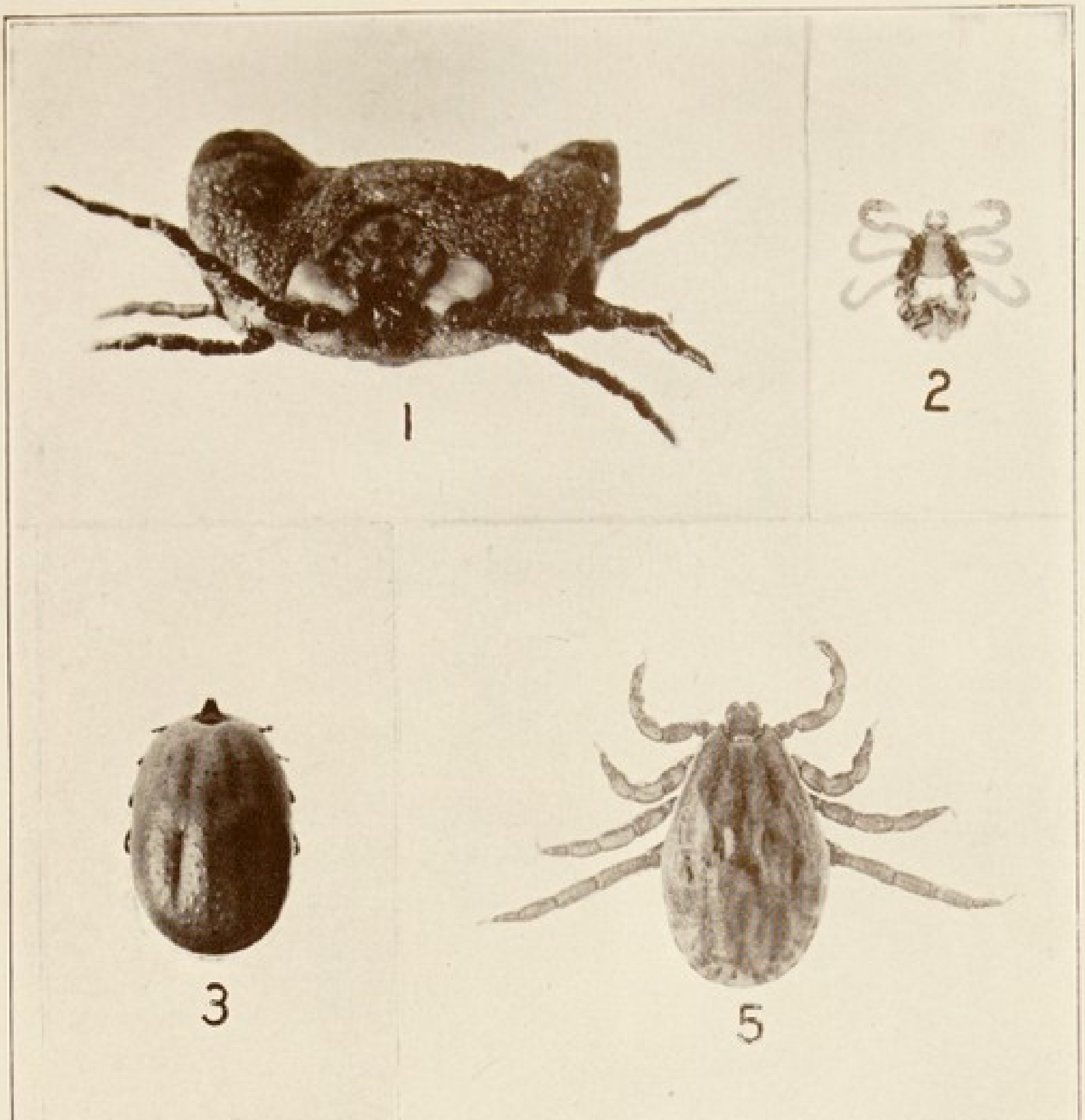
The part played by animals in acting as carriers for the protozoan diseases is of greater importance for they may act as the natural reservoirs of the virus and are thus responsible for the continued existence of the disease. Among the animals that act as carriers of the protozoa, the insects rank first. Their relation to the animal germs is a passive one when they accidentally convey them and active when they are really diseased. The fly feeding upon the excreta of typhoid patients may carry the typhoid germs on its body and when it alights upon food simply leave them; or the anopheles mosquito may be diseased by the malarial plasmodium and under proper conditions on biting a person transmit the malarial germs. The bubonic plague furnishes one of the best illustrations of the part played by insects in acting as carriers. This disease is spread by the bite of fleas which come from rats or squirrels that have been infected. The plague bacillus develops in the digestive canal of the flea and escapes with the excreta while the flea seems to be unaffected by the presence of these germs, if the excretal matter of such fleas comes in contact with a wound, according to Hindle, the infection occurs, although it may be contracted through the salivary secretion.

Fig. 177



Map showing region in the United States in which the Rocky Mountain spotted-fever tick occurs. The degree of shading indicates the relative abundance of the tick in different sections. (From Bishop.)

Spotted fever is a disease of human beings which has been known in certain regions in the Rocky Mountains since the time of the first white settlers and probably existed among the Indians before the



The Spotted-fever Tick (Dermacentor Venustus and Dermacentor Albipictus). (Hunter and Bishopp.)

1, adult spotted-fever tick which has deposited eggs; 2, larva of spotted-fever tick; 3, engorged nymph of spotted-fever tick; 4, the same, ventral view; 5, adult male of *Dermacentor albipictus;* 6, adult female of *D. albipictus,* unengorged.

whites came. This is a disease that has been but recently worked out. The fever is transmitted in nature only by certain ticks, and the only way to eradicate this disease is to destroy the ticks because there is no way at present of curing spotted fever. The spotted fever tick itself shows a rather wide distribution as indicated in Fig. 177. The tick passes through the four stages common among insects, egg, larva, nymph, and adult. The young larva must feed upon blood, usually that of ground squirrels, for from three to five days. It becomes filled during this time and then drops to the ground, where it is protected. After resting from six to twenty-one days, the skin is shed and an active eight-legged nymph appears. The nymph must find lodgement upon some host where it can suck blood, and this requires from three to nine days. Again the tick drops to the ground and now develops into the adult. Before reproduction can take place the male and female feed upon the blood of some animal, usually a large domestic animal. After fertilization the female drops to the ground and lays her eggs, and the cycle is begun again. The adult ticks have become adapted to living on large mammals, and the larval stages are likewise adapted to living upon small mammals. The disease may be due to some bacillus, according to Richet, and is invariably transmitted by the bite of the tick. There are now a large number of diseases which are known to be transmitted by some animal acting as a carrier. The most recent announcement is that poliomyelitis is carried by the common stable fly.

The Prevention of Disease.—This is the field in which humanity can do its greatest work. The task is stupendous. The mere fact that certain diseases, like hookworm, extend in a belt around the world and among the lowest forms of civilization, that tuberculosis is killing thousands annually, that malaria and yellow fever have devastated cities, and bubonic plague unrestricted may sweep through a nation, reveal something of the scope of the problem of prevention. All diseases which are due to the presence of some organism are preventable, and this fact alone is one to furnish all with enthusiasm for a work that must continue for many years to come. In the United States an important fact which indicates that there is a responsibility in the matter of preventing disease is the recent decision of one of the courts in Minnesota that a city is responsible for the purity of its water supply, and that when a person contracts typhoid fever and dies his heirs can sue the city for damages. The recognition of this fundamental fact that a city is responsible for the spread of preventable disease is an indication of progress. The world-wide dissemination of the real facts of disease is an undertaking which will require years but must be accomplished in order to prevent the spread of plague from nation to nation.

Scientists are now able to approach this problem of prevention in an intelligent manner because of the recent discoveries in regard to carriers.

The first step in the progress of prevention is to destroy the insect carriers when practicable or to destroy or prevent their eating in order that they may not be able to reproduce.

In the case of human beings who act as carriers, these must be isolated until free from the germs or prevented from working at trades such as dairying and cooking which enable them to spread the germs. It is sometimes necessary to quarantine chronic carriers. The insect carriers with proper care can be prevented from biting human beings, as is illustrated by the conditions in the Panama Canal zone which used to be like Havana, a pest-hole of disease. After a time the insect carriers must become free from disease germs, if the germs are not allowed to gain access to them. When civilization has developed to the stage that all realize that disease from parasitism is wholly preventable and that for every one of such diseases some one has been careless, then we may expect all to take such interest that the recognized sanitary precautions will be observed. After the greater part of the United States has been free from any epidemic of smallpox for some years, people grow careless and neglect to be vaccinated and it breaks out again. Eternal vigilance is going to be the price that all must pay for protection from the preventable diseases even after their prevalence has been greatly reduced from what it now is, even after the world recognizes that the problem is a work in which every nation must do its part.

Immunity.—Disease has been known from remote times and yet numerous plants, animals, and men inhabit the globe. These have survived the ravages of disease or have never succumbed to infection. It is well known that there is a natural resistance to disease which is held unequally by men; some are never sick and others seem to be unable to resist any form of disease. Again our powers of resistance are higher under certain conditions than others. This power to resist the organisms that invade our body is immunity, and natural immunity is the degree of immunity that each possesses. Immunity has two aspects—resistance to the microörganisms and resistance to the microbial poisons.

When microbes gain access to the body of a paramecium, for example, the paramecium treats them as it would any ingested particle of food, and if the protecting cell walls of the germs cannot be broken down the germs are eliminated. If the microbial toxins are brought in contact with these ciliate protozoans and others there is no appreciable affect upon the protozoa. They are able to tolerate the poisons. It has been known for some time that these simple animals are able to adapt themselves not only to altered physical conditions but to endure the toxic action of true poisons. In studying the fundamental properties of living matter this adaptability of living protoplasm must be ranked as one of the most important.

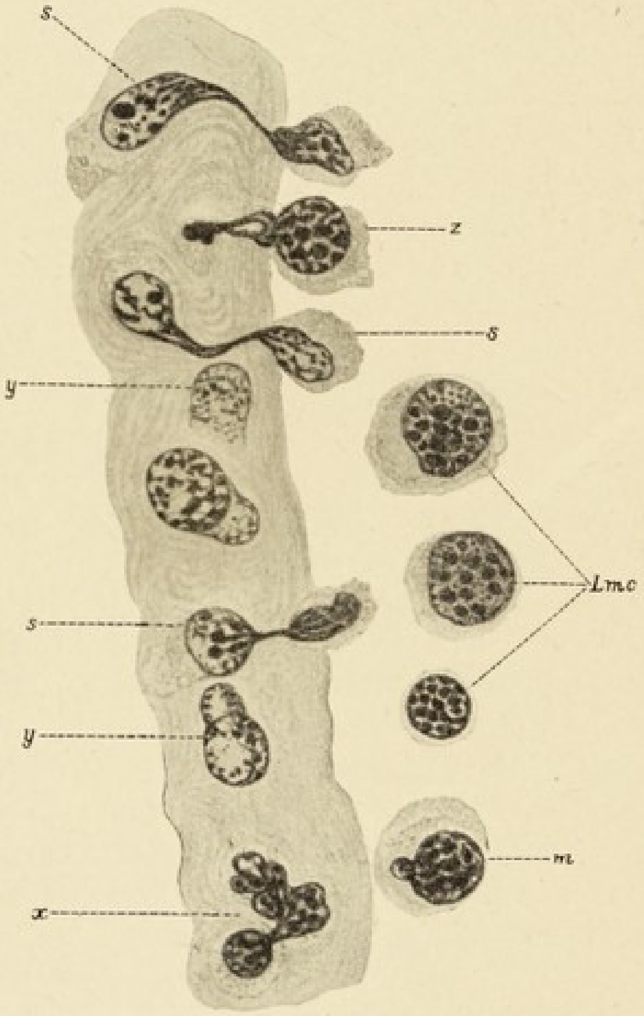
The problem of immunity is further illustrated by the degree of tolerance which different animals have to the same poisons. It is well known that the sheep are the most susceptible of the mammals to the toxin of tubercle bacilli, while the guinea-pig is not very susceptible; but the guinea-pig is very susceptible to the tubercle bacilli and the sheep is very resistant, immunity to the poisons and to the germs are two distinct conditions. The snail (*Helix pomatia*) resists the introduction of large quantities of anthrax bacilli and they soon disappear from the blood to be found in the cells of the foot and especially those which surround the pulmonary vessels. During this taking up of the anthrax bacilli the snail remains in good health. Forty-eight hours after the injection of the bacilli, these cells gave cultures which were capable of giving fatal anthrax to mice. Ten days or more passed before the phagocytes which had engulfed the bacilli had fully digested them. If anthrax bacilli are injected into the body of the perch, numerous leukocytes accumulate around and ingest them, although the peritoneal fluid furnishes a suitable culture medium for these bacteria. These and many other illustrations that might be added serve to show that many animals have a natural immunity not only to the microbial poisons but also to the microbes themselves.[1]

Given this natural immunity which is found to be generally distributed among all forms of life, how does it happen that there is any sickness? It is not easy to answer this question in a word or in an elementary course, but it may be suggested that a sufficient number of germs is necessary within the body, and that these germs must be virulent and the host receptive. We are unable to state

[1] For the detailed study of Immunity, the student is referred to Metchnikoff, Immunity in Infectious Diseases; Ehrlich, Studies on Immunity.

just what the conditions are that make a host receptive to germs or how to eliminate the condition. We say that the non-resistant host is susceptible, the resistant immune. When the germs have gained entrance to a susceptible host does the disease begin as a result of their parasitic habit or are there other factors? The parasitic nature

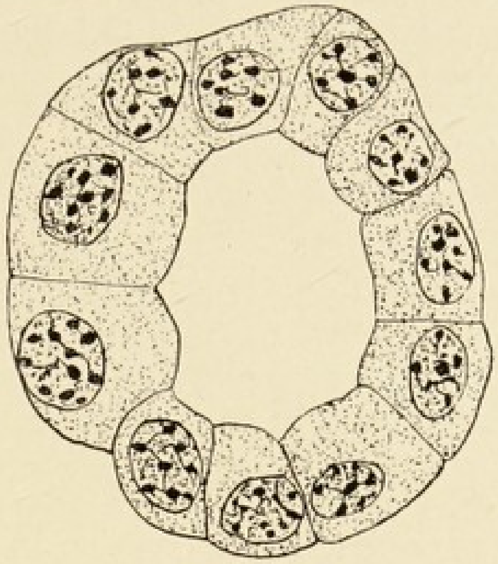
Fig. 178



Migration of lymphocytes through wall of capillary *x; y y*, nuclei of vessel wall cells; *Lmc*, lymphocytes; *x*, irregular shape of nucleus of lymphocyte in process of passage. (Maximow.)

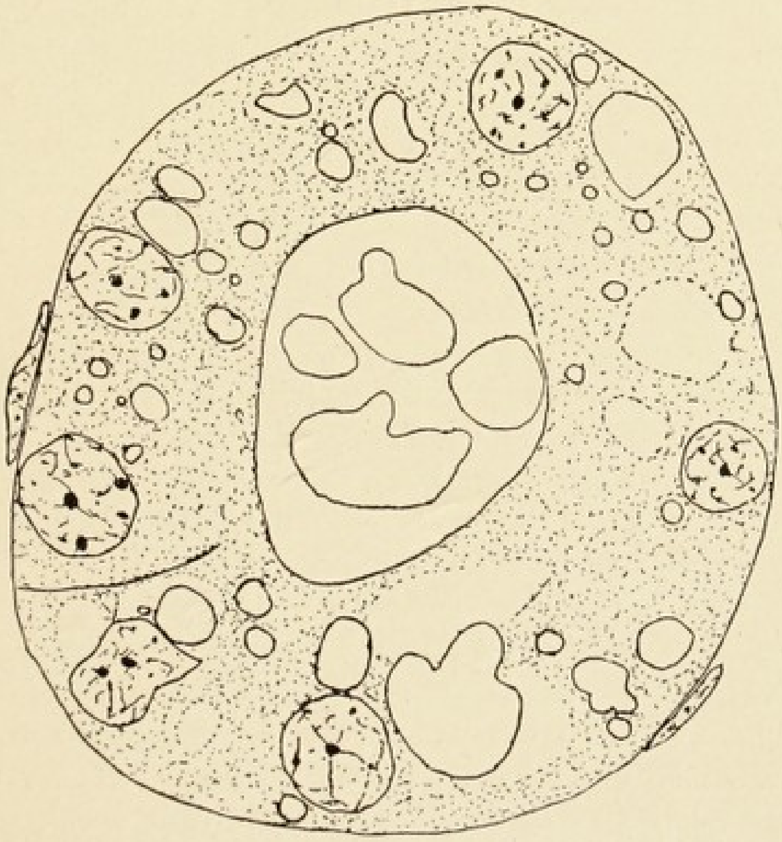
of disease was the early conception, but it was soon found that there were a number of conditions that mere parasitism did not explain. The disease frequently followed a course that suggested that it was similar to the fermentative action of yeast, etc., and so there arose the zymotic theory of germ disease. Later it was found that the natural living processes of the bacteria produced certain waste substances which were of a poisonous character and that some of the

Fig. 179



Kidney cells of normal frog.

Fig. 180



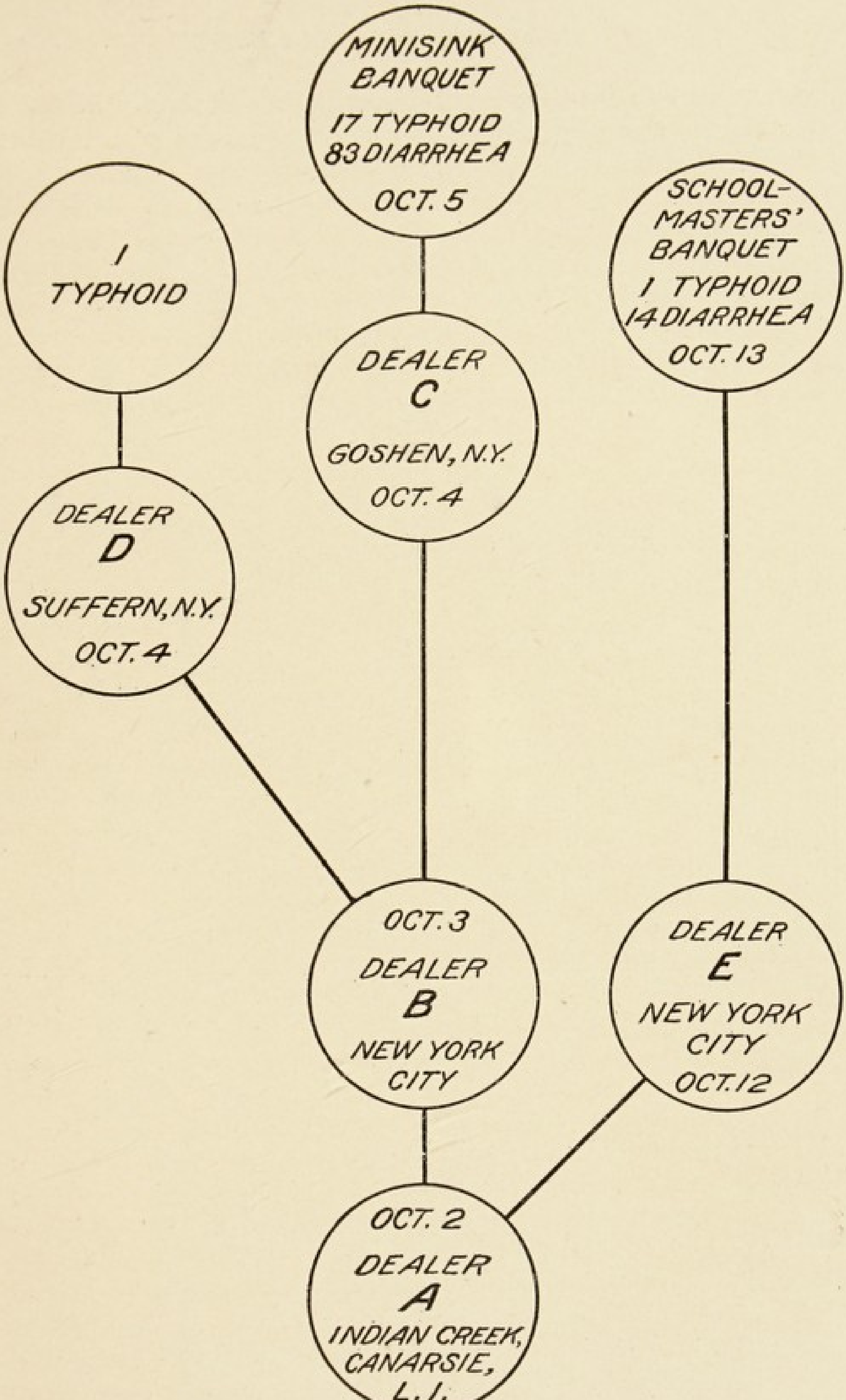
Cross-section of kidney tubule of hemorrhagic frog. The bodies with a continuous outline in the lumen and in the cytoplasm are the degenerating red blood corpuscles. Kidney cells of the frog in a phagocytic role (Anat. Auz., 1908, Bd. xxxii, No. 8).

phases of a given disease could be induced by injecting the poison. There was thus added the toxic factor of disease. Many writers hold that these two processes should be united and that the cause of the disease is "zymotoxic." The details of this theory as well as the details connected with recovery from disease are taken up in advanced courses. It must suffice here to mention in brief outline some of the main points.

The disease germs are destroyed by the phagocytes which ingest them and this process is fundamentally a feeding process just as is the case in the protozoa, but they are also destroyed by the juices of the body. It is believed that the body is able to secrete certain substances (antitoxins) which have the property of neutralizing the toxic products of the bacteria and this gives the cells of the body a chance to recover. As a result of having had certain diseases one is said usually to be protected from a second attack. This is the case with most of the childhood diseases such as measles, whooping cough, etc. When the cells of the body have become thus protected against a second attack, the term *acquired immunity* is used to distinguish it from the natural immunity which was not sufficient in such causes to prevent the disease. Acquired immunity is not a permanent condition of the cells and may disappear after one, two, three, or more years.

Protection an Adaptation.—Since Jenner in 1798 attempted to imitate Nature and produce an immunity to certain diseases, men have been anxious to find a means of protecting their bodies from the ravages of disease. There are now some dozen or more diseases which have their antitoxine, vaccine, etc. If it were possible to remove the germs which cause disease, all of these would be unnecessary. The underlying principle in the use of these protective agents, and there must be a specific one for each disease, is gradually to accustom the cells of the body to the poison in a mild form so that during the process they will elaborate antidotes to the particular poison produced by the given organism. The principle thus employed is as old as the study of biology and is everywhere apparent in nature. This adaptation is one in which the living protoplasm of certain cells plays the important part. Tuberculosis may occur in the lungs, diphtheria has its location in the throat or nose, while typhoid fever is found in the blood and may be localized in the intestines, and it may be assumed that the cells which acquire an immunity to each of these diseases are not the same. In vaccination against smallpox, the germs of cowpox, a mild form of smallpox, are

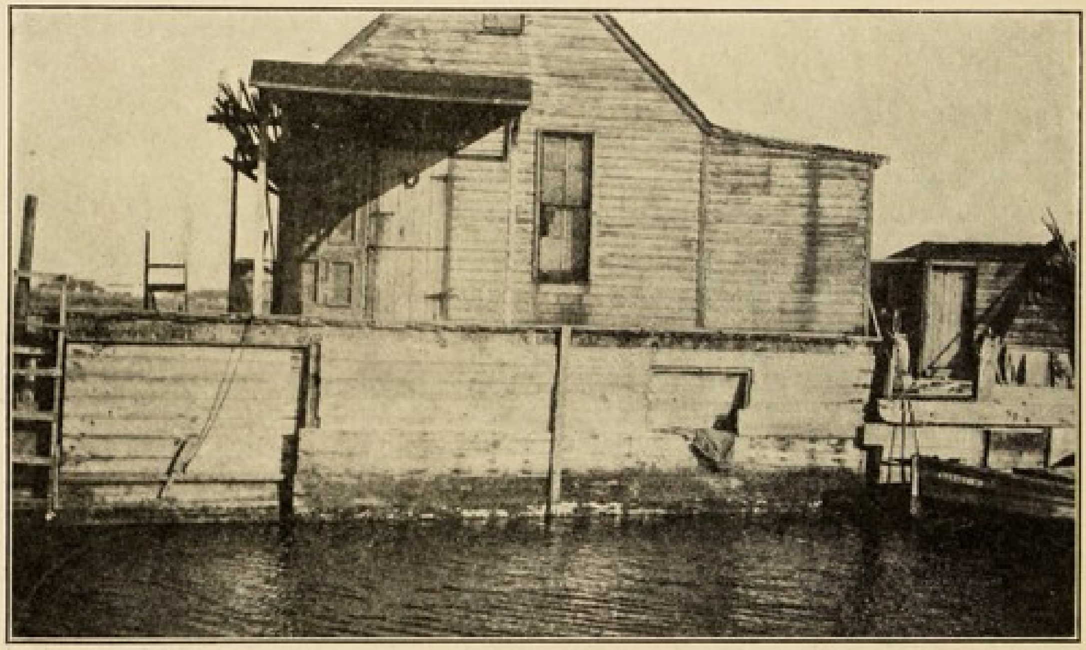
Fig. 181



Cases of typhoid and enteritis traced back to Rockaway oysters sold by dealer *A*. (George W. Stiles.)

introduced into the body and through the reactions of the cells of the body to the cowpox virus, the subject acquires a greater power to withstand the virulent smallpox virus. This acquired toleration lasts through a variable number of years but usually not more than seven. Intelligent people always keep themselves immune to smallpox, because no one can tell when or how he will be exposed. The United States, England, and Germany are immunizing their soldiers against typhoid fever, and the results up to the present are very successful and apparently will be of value in civil life. The shop,

Fig. 182

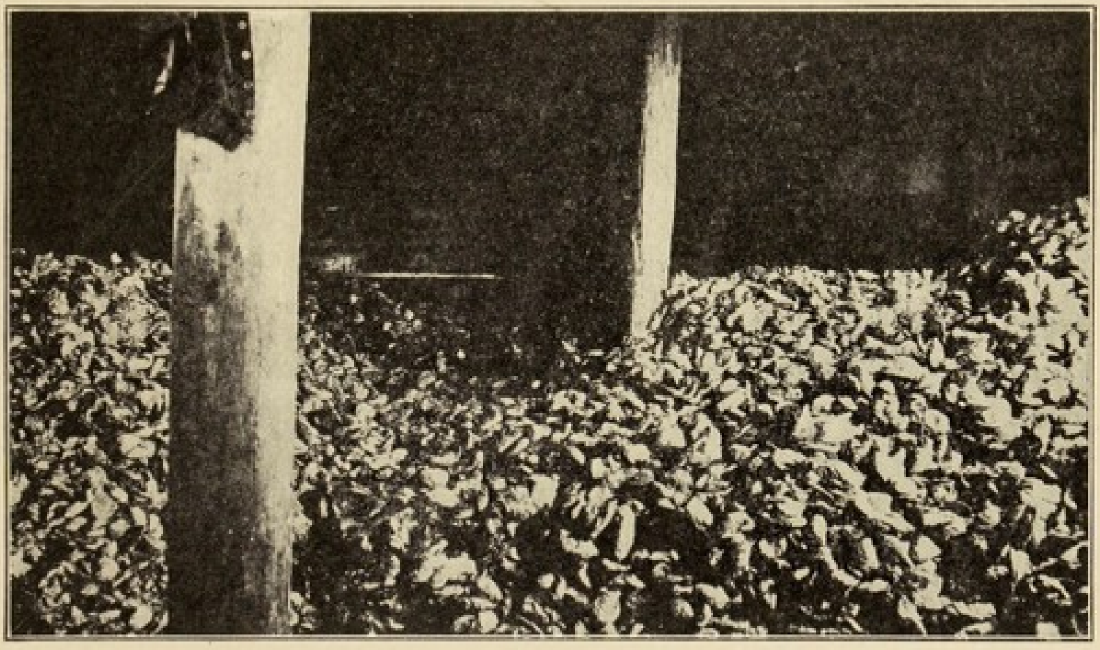


Oyster house of dealer *A* at Indian Creek, near Canarsie, Long Island, N. Y. Photograph taken January 25, 1912, with the tide rising. Note the closed trapdoors through which oysters are unloaded from boats. A trapdoor in the floor above permits entrance from the interior of the building. (George W. Stiles.)

the factory, the dairy, the mine, the canning industry, the meat-packing concerns, etc., all have or must adopt a new regimen as a result of the discoveries in biology during the past twenty years. State and National legislation is being enacted to compel such industries to recognize the fundamental rights of human beings to have a clean place to work, a clean place to live, and clean food to eat. The interrelation and interdependence of the human family is well illustrated in the following:

The epidemic of typhoid fever and other gastro-intestinal disturbances following the Minisink banquet might be duplicated in so far as the biological principles are involved by many examples. There were 155 guests at the Minisink banquet and within a short time afterward a large number of illnesses occurred. The graphic statement in Fig. 181 shows that nearly all were sick, and when the history of each case was known it was found that those who were sick had eaten oysters at the banquet. After a painstaking examination of the facts connected with the collection, storage, and shipment of the oysters it was proved that the bacteria in them were the cause of the illness that followed the banquet. The oysters used were

Fig. 183

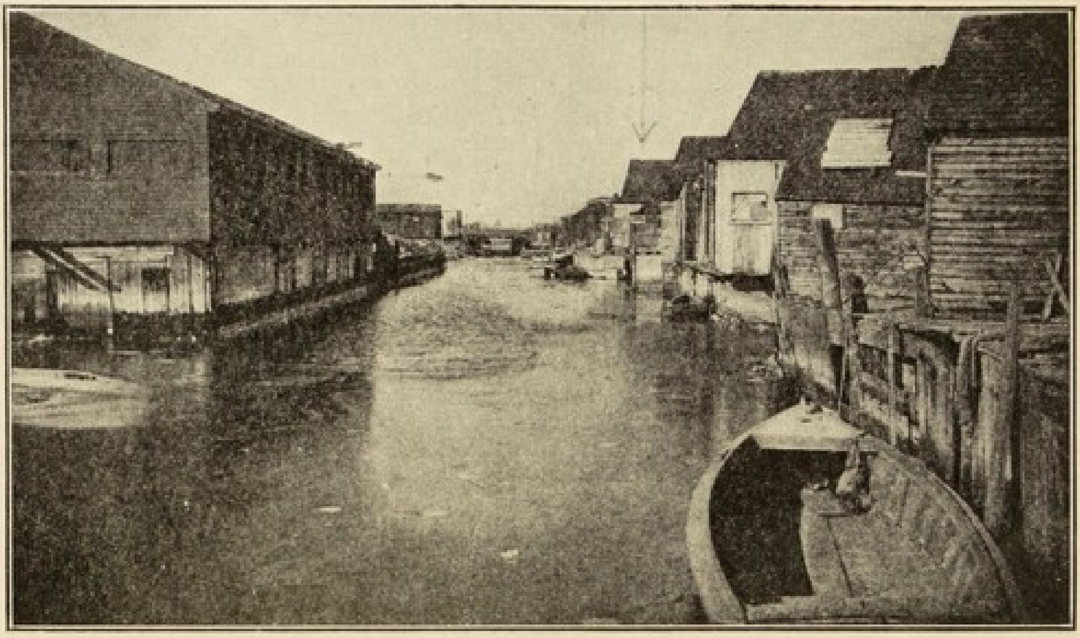


Oysters in the cellar under the house of dealer *A*. Photograph taken December 15, 1911, at low tide, when only a portion of the shells were under water. (George W. Stiles.)

collected from oyster grounds in Jamaica Bay which are polluted with sewage. They were then taken to Indian creek near Canarsie, Long Island, and placed in the dealer's cellar as shown in Fig. 183. The bacteriological examination of the water and oysters collected from Jamaica Bay shows that the water was dangerously polluted. Typhoid fever bacilli were isolated from oysters as well as *Bacilli coli* and others which would give all of the germs necessary to account for the illness which followed the banquet.

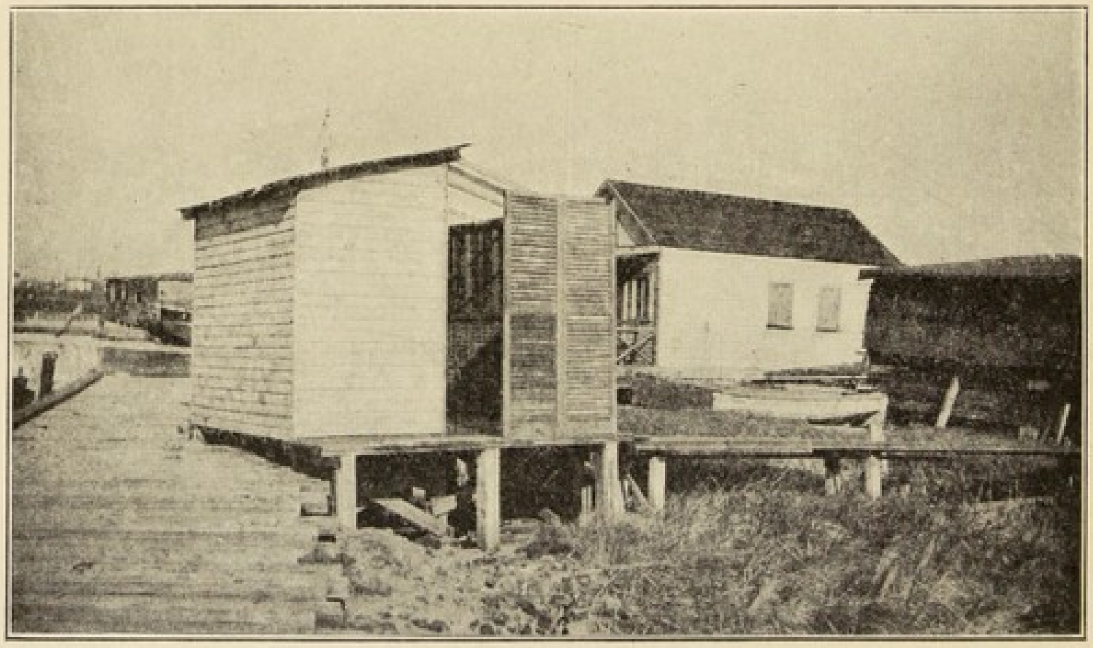
The details of this case are given to show how much we are dependent upon others for our food and how little most of us know

Fig. 184



View of Indian Creek, near Canarsie, Long Island, where nine oyster dealers float oysters in the cellars of their houses. The arrow points to dealer *A's* house. (George W. Stiles.)

Fig. 185



A three compartment privy located directly over Indian Creek not far below dealer *A*. This is one of the immediate and specific sources of pollution in this creek. (George W. Stiles.)

about the conditions which obtain in the collection and preparation of this food. The dealer who supplied these oysters was ignorant of the detailed biological information involved. Business men at the banquet were kept from their work for weeks because of his ignorance or wilful neglect of sanitary regulations. The problems of protection against disease are interwoven with many established industries which must be made to recognize the fundamental principles of disease and its spread. This will require a long period of agitation and a more perfect Board of Health organized as a National department and having charge over the great problems of the spread of disease. Many improvements are bound to come along this line of protection in the next few years.

CHAPTER XVI

EVOLUTION

As the word evolution came into early use, it had reference to the manner in which organisms during growth gradually acquire adult characters. Thus the notion of an unrolling or unfolding was from the first associated with the term. Such a view assumes that certain conditions have preëxisted and that there is a direct relation between the structures that finally appear and those that give rise to them. The most important part of this early conception is the part which has to do with the idea that present conditions are related to past causes. A large literature has grown up around this theme which has now become a household word; and, in this elementary introduction to evolution, one cannot hope to do more than explain some of its relations to biology. An understanding of evolution involves a knowledge of heredity and variation such as is presented in the following chapter. A recent writer suggests that the word evolution is now legitimately used in four different senses. "It is the name of a branch of science; it is a theory of organic existence; it is a method of investigation; and it is the basis of a system of philosophy." (Jordan.)

Organic evolution is the name of a branch of the science of biology, and it has for its purpose the study of the relations of organisms to the unchanging laws of nature. As soon as one tries to find a leaf that is unchanging day after day, or an animal that does not vary any from week to week, one begins to realize that there is a great deal of change going on in living things. Environment is not constant and the changes in an organism are greater than most of us realize. The animal and the plant change form and grow new parts but neither ever regains its first form. But the conditions of life, growth, and death are ever the same. In whatever place life happens to be or in whatever state, it is continually subject to the unchanging laws of nature.

"But the things we know do not endure. Only the shortness of human life allows us to speak of species or even of individuals as permanent entities. The mountain chain is not more nearly eternal than the drift of sand. It endures beyond the period of human observation; it antedates and outlasts human history. So does the species of animal or plant outlast and antedate the lifetime of one man. Its changes are slight even in the lifetime of the race. Thus the species, through the persistence of its type among its changing individuals, comes to be regarded as something which is beyond modification, unchanging so long as it exists. 'I believe,' said the rose to the lily in the parable, 'I believe that our gardener is immortal. I have watched him from day to day since I bloomed, and I see no change in him. The tulip who died yesterday told me the same thing.' As a flash of lightning in the duration of the night, so is the life of a man in the duration of nature. When one looks out on a storm at night he sees for an instant the landscape illumined by the lightning flash. All seems at rest. The branches in the wind, the flying clouds, the falling rain, are all motionless in this instantaneous view. The record on the retina takes no account of change, and to the eye the change does not exist. Brief as the lightning flash in the storm is the life of man compared with the great time record of life upon earth. To the untrained man who has not learned to read these records, species and types in life are enduring. From this illusion arose the theory of special creation and permanence of type, a theory which could not persist when the fact of change and the forces causing it came to be studied in detail." (Jordan.)

Evolution is a method of study which is applicable to all forms of problems. It suggests that the present conditions of nature explain past changes and that the present is understood in the light of the past; in short that there is a causal relation between the present and the past whether it be in the origin of an organ or whether it be the Crusades in history. "Whether planets or mountains or molluscs or subjunctive modes or tribal confederacies be the things studied, the scholars who have studied them most fruitfully were those who have studied them as phases of development. Their work has directed the current of thought." (Fiske.)

Evolution is a theory of organic existence in that it seeks to explain the origin of organs, the formation of species, and the divergence in plants and animals. This will form the main part of this chapter.

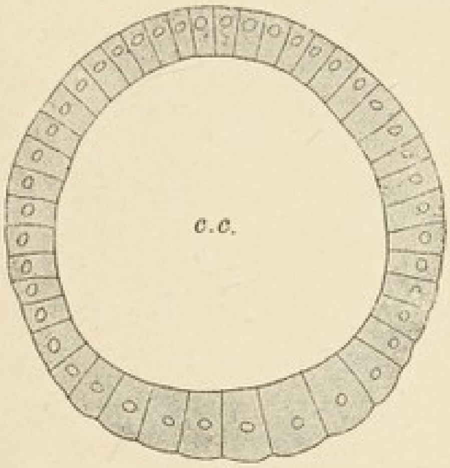
Evolution as a philosophy is applied when discussing what various men have conceived to be the manner in which new species have come into existence how the earth was formed, or the stars and planets derived from the original nebulæ. This is the phase of evolution concerning which there are various views and about which there will be more in the future. The latter part of this chapter will present extracts from the philosophy of evolution as Lamarck and Darwin have expressed it.

SOME EVIDENCES OF ORGANIC EVOLUTION

Fundamental Characteristics of Living Things.—In every animal and plant studied or referred to in this course there have existed certain fundamental likenesses. There are always present specific chemical substances united in such a way as to form protoplasm. No matter how highly differentiated this protoplasm becomes, whether it forms a part of the nerve cells of a genus or the roots of a tree, it is fundamentally the same in composition. Metabolism is a term that includes many changes associated with the building up and tearing down processes of living protoplasm and in all life it is essentially the same, and could we explain it fully in one plant or one animal we could explain it fully in all. Every living thing in the world today came into existence through the direct influence of some similar form of life. This statement will remain true as a characteristic of life and as evidence of relationships in life no matter if life should arise spontaneously in the future. The important fact is that the present forms of life on the earth are genetically related. These are fundamental facts concerning which all are in agreement and they predicate distinct aspects of relationship between organic beings. The complex characteristics existing in all organisms do not arise independently with the birth of a new rose plant or new fly, but are handed down from the parent rose and fly. In a similar manner these characters have been passed on to all, beginning with the simplest and gradually extending to the more complex.

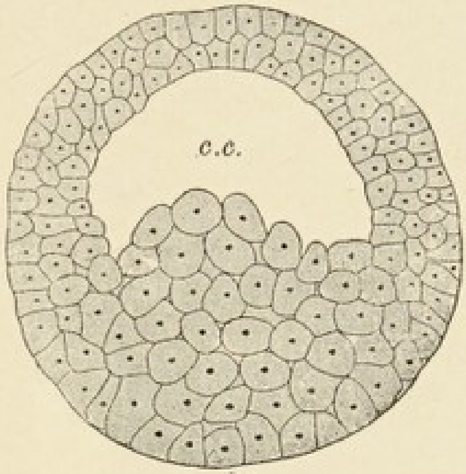
Embryology.—Every living thing is capable of being analyzed into a common structure, the cell, which is the smallest unit of structure in which life can independently exist. The origin of new individuals in nature begins by the formation of this unit of structure. In the simpler types of life, this consists in growing a cell like the parent cell; but in all the highly differentiated organisms, the adult condition is reached only after a period of growth. The changes through which the frog or chick or man passes in developing from the one-celled stage to the adult are regular and constant. The fertilized egg cell begins to segment, that is, to grow new cells, and continues until the cells become definitely arranged into layers. These cells, alike in size and kind, are first arranged in two specific layers according to their relation to the future longitudinal axis of the dorsal or median side of the adult. As soon as this disposition of the cells occurs, the embryologist can locate the regions from which the adult

Fig. 186



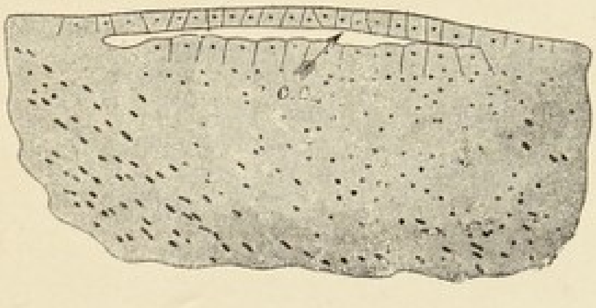
a

Fig. 187



b

Fig. 188

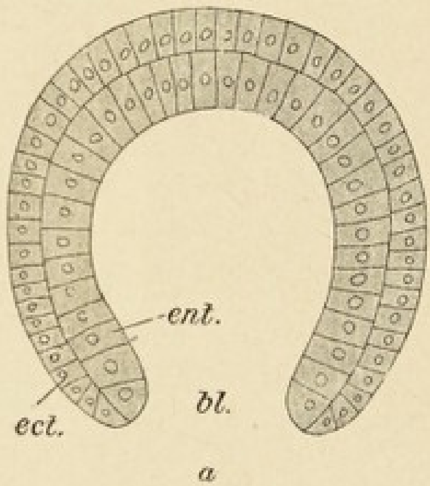


c

Section of the blastula stage. Fig. 186, blastula of *Amphioxus;* Fig. 187, blastula of triton (amphibian); Fig. 188, blastula of bird; *c, c,* cleavage cavity. (After Hertwig.)

organs are to arise, and because of this fact these two layers are known as germ layers. A little later, a third germ-layer is formed between the earlier two. It is important to realize the significance of these germ-layers, for they are present in all of the vertebrate animals and many of the invertebrates, in a similar relation both as to origin and as to subsequent history. The detailed history of the germ layers is too technical and extensive for our purpose but we may indicate the more important results. From the outer germ layer arise the skin, the nervous system entire, and the tissue lining the anterior and posterior parts of the alimentary tract. The middle germ-layer is transformed into the muscular system, blood, blood-vessels, reproductive organs, and certain outer layers of the alimentary canal, while the inner germ-layer becomes the lining of the alimentary canal, the lungs, the liver, and the pancreas. In all of these wonderful changes there are no breaks but serial transformations—the simple giving rise to the more complex—the general becoming specific, and we speak of this as a process of differentiation. Do all of the adult organs form in the most direct manner possible and is Nature economical in utilizing the most expedient measures in producing them? Let us examine one or two organs as examples.

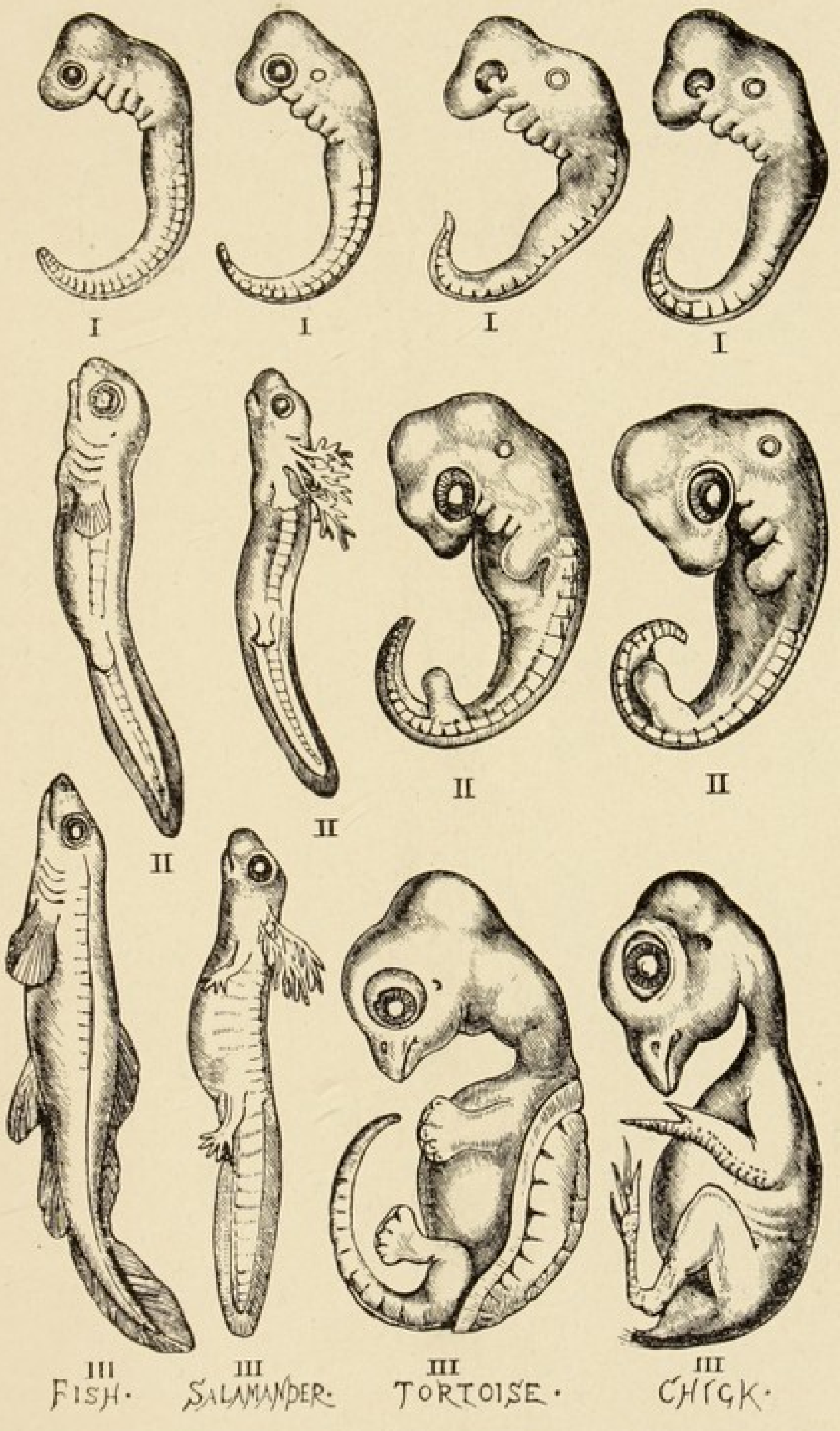
Fig. 189



The process of gastrulation. Gastrula of amphioxus. *ect*, ectoderm; *ent*, entoderm; *bl*, blastopore or primitive mouth. (After Hertwig.)

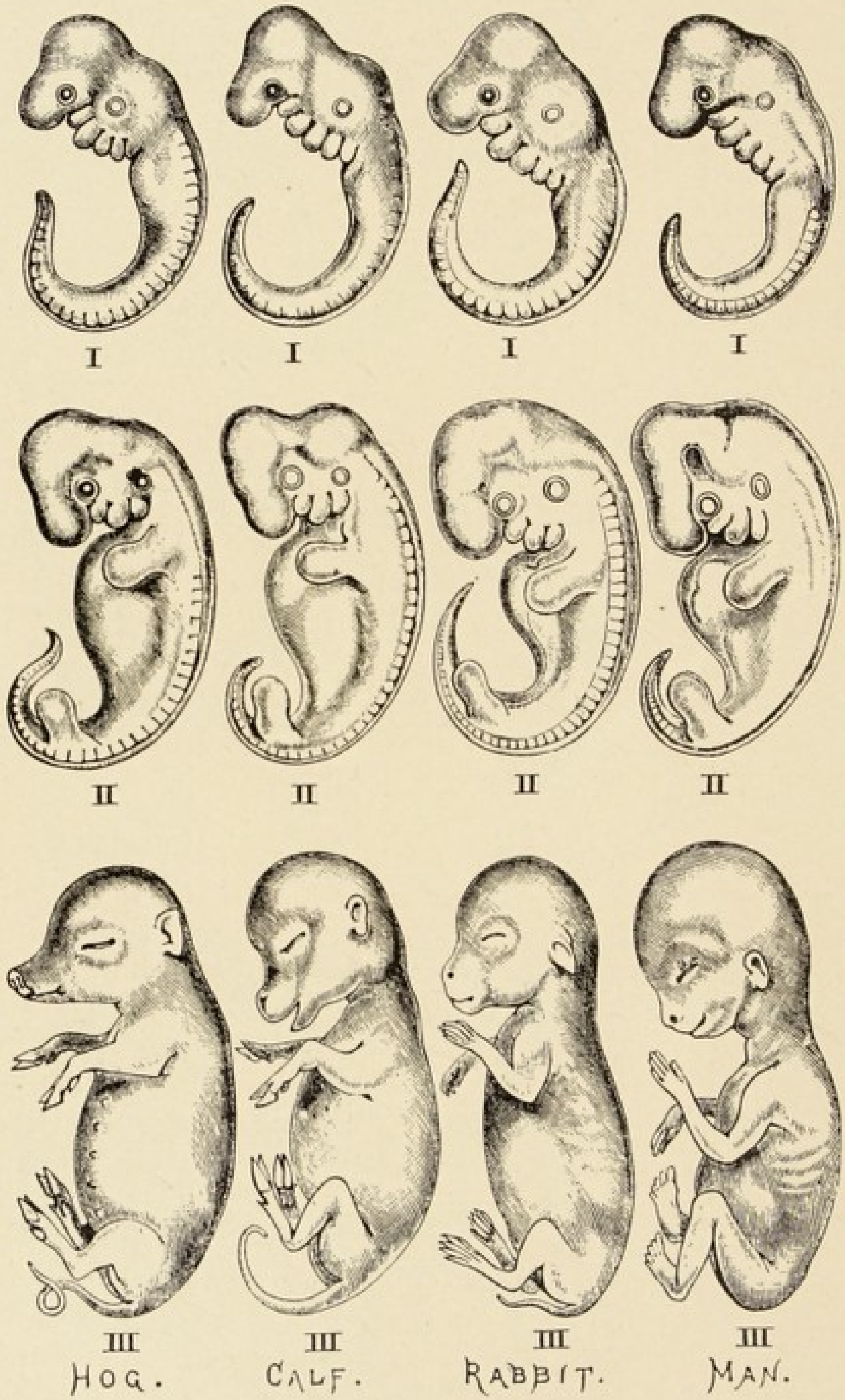
During the early growth of the human embryo there are found in the side of the neck a number of openings which can easily be seen; these are in position and shape similar to the gill openings in the neck of the adult fish. After a time, the tissues on each side of these embryonic structures are transformed into the lower jaws, the bones in the ear, and the larynx. It requires energy and time to form these useless openings in the neck and it is a circuitous method of producing the needed and necessary adult parts. The openings are known as gill-slits or gill-clefts and are likewise found in the embryo of birds, reptiles, amphibians, and fishes. A critical study of their origin indicates that they are the same in each group of animals where they exist. Nature is very extravagant in the method employed in producing some of the adult organs in man.

Fig. 190



A series of embryos at three comparable and progressive stages of development (marked I, II, III), representing each of the classes of vertebrated animals below the mammalia. (After Häckel, with permission of the Open Court Publishing Co.)

Fig. 191



Another series of embryos, also at three comparable and progressive stages of development (marked I, II, III), representing four different divisions of the class mammalia. (After Häckel, with permission of the Open Court Publishing Co.)

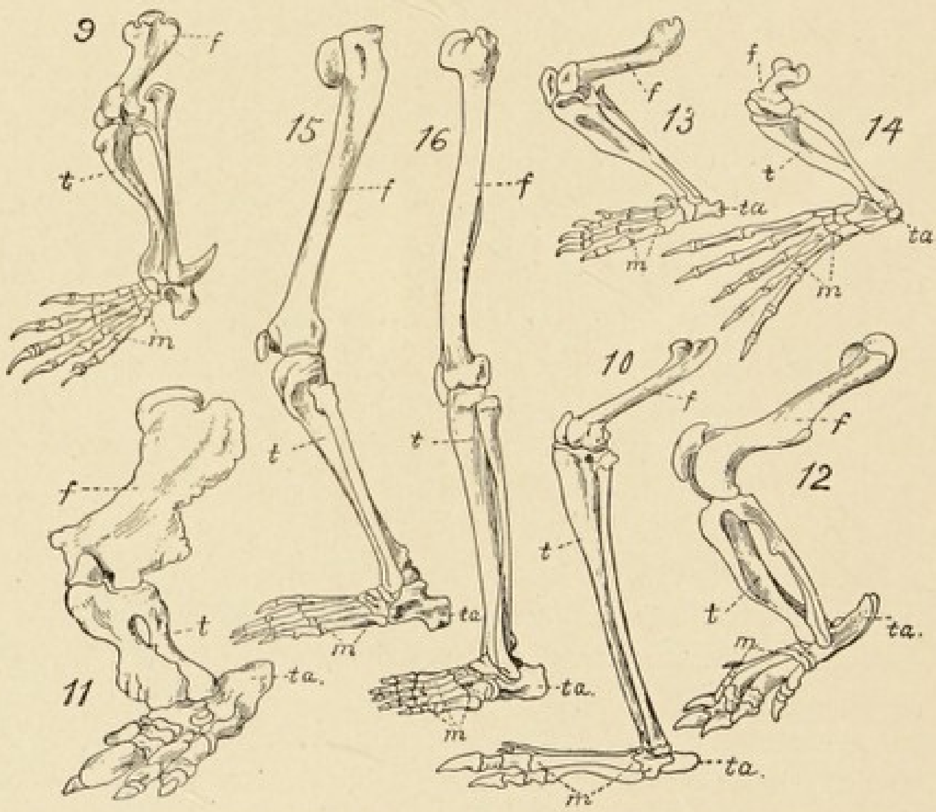
Intimately associated with the formation of the embryonic gill-clefts, are accompanying changes in the bloodvessels just after they leave the heart. There is present in man one large artery from which others arise; this artery extends from the heart to the posterior regions of the abdominal cavity and is called the aortic arch in the region near the heart because of its embryonic history; for in the embryo there are well-defined aortic arches which pass around by the neck having a gill-cleft between them. What becomes of them? They are absorbed, but one remains in the adult and we know just which one of the six branches it is and can predict with assurance that this specific branch will be the one to persist.

These illustrations are sufficient to present the next principle of development, namely, that the adult organs are products of the past and so indelibly has the past stamped itself on the present that the growing organism cannot avoid travelling many circuitous routes before reaching its adult state. In our embryologies this principle is known as "recapitulation" and means that the adult passes in its embryology through certain ancestral stages and that from these stages some idea of its remote ancestry is obtained. This theory in various forms is a part of all works on embryology; it has been attributed to several men but is found in writings that antedate Häckel and von Baer. All of which simply means that all students of embryology from the first observers of the developing chick down to the present time have been profoundly impressed with this tendency of the embryo to go through many needless processes. One writer characterizes the human embryo as an "old curiosity shop" where unknown and obsolete parts, absent in the adults, are to be found. We need not concern ourselves with the shades of interpretation nor the quarrels of theorists, but with the fundamental facts that the embryo of all of the higher animals exhibits many curious structures that do not appear in the adult, and the best scientific explanation accepted today is that they are inheritances from the remote past.

The evidences which embryology furnishes of the relationship and derivation of animals or of plants is regarded as very important.

Homology.—The similar manner in which the same parts in widely different animals develop enables the expert to detect important relationships. An examination of the skeletons shown in Figs. 1 to 5 (pp. 19 to 23) indicates that the vertebral column of one contains the same kind of vertebræ as those in all the others. The bones in the arms and legs show the same fundamental number of elements, although variously modified (Fig. 192). The bones in the wing of a bird are like those in our arm although there are more bones in our wrist, but in the embryonic wing the missing bones are present. Some adult organs thus reach their state through a growth from the simple to the complex, and later assume the simpler form. Many other common relations and organs are associated in animals that possess a backbone such as a dorsally placed nervous system containing a neurocoele, a ventral cœlome containing the organs of digestion, reproduction, etc. But no matter how numerous these similarities are, they never amount to identity.

Fig. 192



Limb skeletons of various animals, showing homologous bones: 9, ornithorhynchus; 10, kangaroo; 11, megatherium; 12, armadillo; 13, mole; 14, sea lion; 15, gorilla; 16, man. (From Jordan and Kellog.)

No matter how different the general appearance of organs or structures, and no matter how different their general function, if they can be shown to have had a common origin, they are said to be homologous. Homologous organs usually have the same relative position on the animal. This means that organic beings are constructed of corresponding parts, and that the only difference between them consists in variations in the original and fixed number of elements. An element may be large in one animal and small in another; simple or complex, etc.

Fig. 193

Archæopteryx lithographica. (After Dames, from Wiederscheim.)

The chief difference in the group of vertebrate animals consists in variations in the number of fixed elements that constitute the typical vertebrate. This study of homology serves to show the relationships in similar and also in some divergent adult morphological structures. The manner in which the differences in these homologous organs have been brought about in Nature belongs to the philosophic phase of evolution, but all are agreed concerning the facts of homology and the relationship thus indicated.

Paleontology. — From the time scientists first began to try to understand the formation of the earth up to the present all have been impressed with the story that is told by the record of the rocks and their fossils. But there are many blank pages and often whole chapters missing whose absence perplexes and disappoints us. A fossil is defined as any part of an organic body that has become definitely preserved in the rocks; the teeth, a feather, or a footprint each tells a truthful story. The fossils show many transitional types of animals between the great groups such as the archeopteryx, part bird and part reptile (Fig. 193). Geology also indicates that all of the great groups of animals were in existence before the age of man, but the beginning of many classes is lost either because no record was preserved in the rocks or else because it has not yet been found. The ancient animals and plants lived and struggled and were parasitized just as organisms live and struggle and are parasitized today; they came into existence in the same way and show the same relationships. Many of the modern phyla would be isolated and aberrant were it not for the fossils which serve to show their connections with well-established groups.

PHILOSOPHY OF ORGANIC EVOLUTION

The several ways in which these facts have been interpreted constitute the philosophy of evolution. Among the men whose names rank foremost in presenting a consistent theory of organic evolution, those of Lamarck and Darwin stand foremost. Each recognizes that evolution has to take living matter which is being continually urged in opposite directions by heredity and by variation. By heredity is meant the tendency which every animal or plant has of perpetuating itself in its offspring. The wolf never begets a dog nor does the rose bush bear lily blossoms; nor can man by all of his skill set aside this tendency; it is as certain as the law of gravitation. But the similarity never amounts to identity; the offsprings exhibit a given amount of difference, small in some instances large in others. These differences are called variations and are of great importance. Were there no variations, there would be no progress; our trees, fruits, horses, cows, etc., of today would be the same as the first tree, the first fruit, the first horse, the first cow, and it would be impossible to improve or change the type.

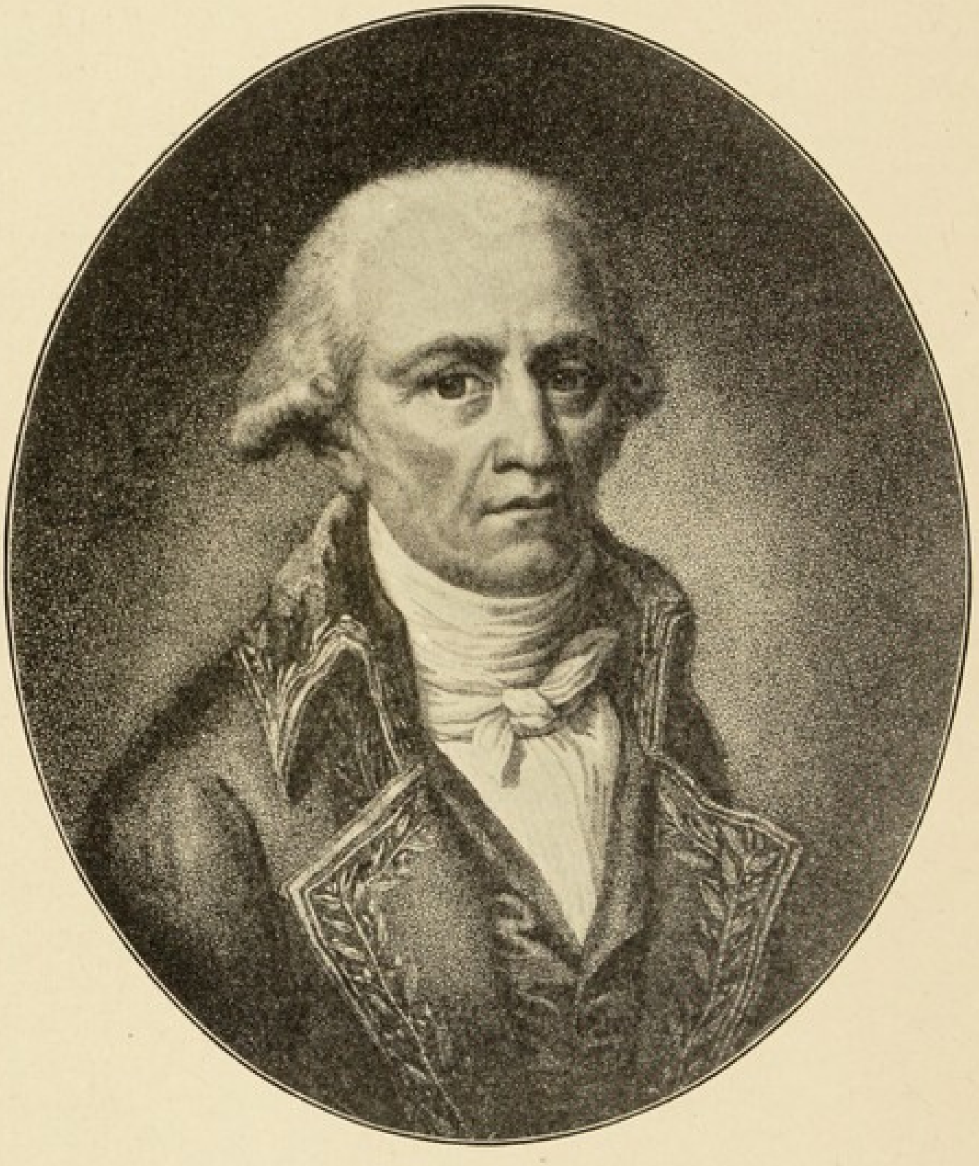
Evolution also has to deal with the prodigality of Nature. The unobservant rarely stop to consider that in the keen contest for food and a place to live animals and plants are in competition especially with those forms with which they are closely akin. The idyllic dream of some who long for a life as free as the bird that darts through the air or the fish that glides through the water is pure fiction. Every living thing has to participate in a contest for its existence more or less severe, because of the limited amount of food and space. Unhindered plants and animals reproduce in geometrical ratio. This latter fact may need illustrating. Robin-redbreast raises annually one or two broods which should result in an average of four young. The following table from Metcalf shows the result for ten years at a similar rate of increase:

	Adult.	Young.
One pair of adult robins	2	4
Second year	6	12
Third year	18	36
Fourth year	54	108
Fifth year	162	324
Sixth year	486	972
Seventh year	1,478	2,916
Eighth year	4,374	8,748
Ninth year	13,122	26,244
Tenth year	39,366	78,732
End of tenth year	118,095	

If even this low estimate should obtain, there would not be enough robin-food in the world for them to live on. Among the fishes the possibility for increase is multiplied many fold, as some single fish annually lay several million eggs and the young become sexually mature in two or three years. The insects furnish additional facts: a single flesh-eating fly (*Musca carnaria*) produces 20,000 larvæ, and these grow so quickly that they reach their full size in five days. The great Swedish naturalist Linnaeus asserted that a dead horse could be devoured by three of these flies as quickly as by a lion. Each of these larvæ remains in the puppa state about five or six days, so that each parent fly may be increased two-thousand fold in a fortnight.

Enormous possibilities of increase are found in nearly all of the simpler animals, and the figures for plants are of a similar nature, but the more interesting fact is that the number of robins, or flies, is not on the increase from year to year—what must then be the death rate for these rapidly increasing organisms? Our authority says: "Taking animals as a whole, it would be safe to say that hundreds of thousands die every year for each one that lives." What

Fig. 194



Lamarck (1744–1829).

holds the animals and plants in check when they are all potentially capable of becoming much more numerous? Starvation, heat and cold, floods, droughts, storms, carnivorous and herbivorous enemies, diseases, etc. Each claims its share. "Nature is fertile in expedients for killing. Life is not easy. Those that live pass through a severe test with the result that only those best fitted for the contest survive —the weaklings have small chance of reaching maturity. In a struggle so severe, any advantage, however slight, of greater vigor or better structure, may be decisive and turn the scale." (Metcalf.)

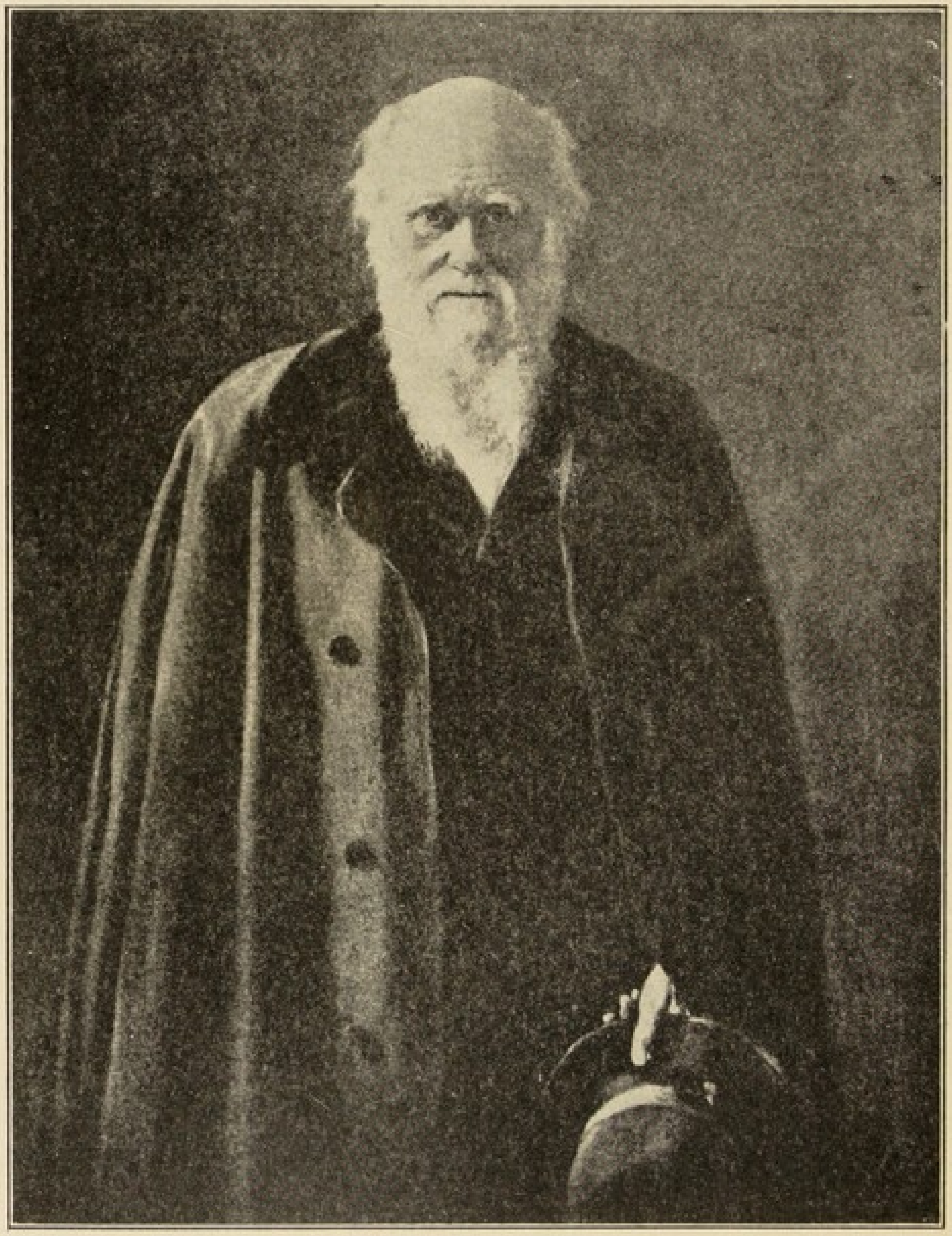
Evolution takes her three tools, heredity, variation, and this result of the prodigality of Nature as the basis of a series of progressive changes. These are the main lines of study and the facts have been grouped about one or the other or all three. Certain works like Darwin's and Wallace's are rich storehouses for those who must derive the facts from reading, but for all Nature is at the door daily waiting to be studied.

Thus far in this discussion all easily agree but when it comes to interpreting the meaning of the changes there are many opinions. Some men of large vision accompanied by a deep study of many facts have given us their explanation. The limits of this chapter forbid extensive review of even two or three of the most prominent writers. Under various guises several of the fundamental features of evolution are found in the writings of men from Aristotle down through the dark ages to Erasmus Darwin (1731-1802), who was a firm believer in evolution.

Lamarck's (1744-1829) life is the old, old story of a man of genius who lived far in advance of his age, and who died comparatively unappreciated and neglected. In this history of the development of the idea of evolution he is the most prominent figure between Aristotle and Charles Darwin. His treatise *Philosophie Zoölogique* shows "first, the certainty that species vary under changing external influences; second, that there is a fundamental unity in the animal kingdom: third, that there is a progressive and perfecting development."

Lamarck is chiefly known for the four laws of evolution which Osborne translates as follows: (1) The Law of Growth. Life by its internal forces tends continuously to increase the volume of every body that possesses it, as well as to increase the size of all the parts of the body up to a limit which it brings about. (2) The Law of Functional Reaction. The production of a new organ or part results from a new need or want, which continues to be felt, and from the new movement which the need initiates and continues. (3) The well-known Law of Use and Disuse. The development of organs and their force or power of action are always in direct relation to the employment of these organs. (4) Use Inheritance. All that has been acquired or altered in the organization of the individuals during their life is preserved by generations and transmitted to new individuals which proceed from those which have

Fig. 195



Charles Darwin (1809–1882).

undergone these changes. Lamarck, like Erasmus Darwin, accepted spontaneous generation, for he held that Nature was always creating elemental plants and animals.

Charles Robert Darwin (1809-1882), the great naturalist and author, by his interpretation as a result of his study, made a most notable contribution to our conception of evolution.

From 1831 to 1836 he acted as naturalist on H. M. S. *Beagle*, which made an extensive surveying expedition. During this time he thought and read about the collections of fossil and living forms made by the *Beagle*, and he says that it was "by far the most important event in my life, and has determined my whole career." On his return, he published his observations in *A Naturalist's Voyage*, which is one of the most delightful records of a naturalist's travels ever produced.

Darwin owed a great deal to his predecessors, more than is generally believed, because a rather complete conception of evolution had already been reached, and some of the evidence stated. He was strongly influenced by reading Lyell's *Principles of Geology*, and later while studying domestic animals he read Malthus *On Population*, as a result of which "the idea of selection in a state of nature first occurred to him as a result of the struggle for existence, or rather for life, between different individuals and species." Darwin's great contribution to evolution is the *Origin of Species* as a result of a struggle, utilizing variations and letting nature select, which is what is meant by the term "Natural Selection" or the "Survival of the Fittest." "Natural selection, then, is a theory which seeks to explain by natural causes the occurrence of every kind of adaptation which is to be met with in organic nature, on the assumption that adaptations of every kind have primary reference to the preservation of species, and therefore also, as a general rule, to the preservation of their constituent individuals."

Variation, then, is the key-note to Darwinism and one of the chief lines of research since his time has been to determine the causes of variation. Some idea of Darwin's notion in regard to variation is to be gained from the following. "It seems clear that organic beings must be exposed during several generations to new conditions to cause any great amount of variation, and that when the organism has once begun to vary, it generally continues varying for many generations. No case is on record of a variable organism ceasing to vary under cultivation. Our oldest cultivated plants, such as wheat, still yield new varieties; our oldest domesticated animals are still capable of rapid improvement or modification."

During the time of Lamarck and Darwin the opinion was very general that species were immutable and remained so unless changed by a distinct creation. Today it is regarded as a difficult problem to formulate a satisfactory definition of species. Darwin maintained that varieties arise through individual differences. "Hence I look at individual differences, though of small interest to the systematist, as of the highest importance to us, as being the first steps toward slight varieties as are hardly worth recording in natural history. And I look at varieties which are in any degree more strongly marked and permanent, as steps toward more strongly marked and permanent varieties; and at the latter as leading to subspecies." . . . "Again it may be asked, how is it that varieties which I have called incipient species, become ultimately converted into good and distinct species, which in most cases obviously differ from each other far more than do the varieties of the same species? How do these groups of species, which constitute what are called distinct genera, and which differ from each other more than do the species of the same genus, arise? All of these results follow from the struggle for life. Owing to this struggle, variations, however slight and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be transmitted to the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection, in order to mark its relation to man's power of selection. But the expression often used by Mr. Herbert Spencer of the Survival of the Fittest is more accurate and is sometimes equally convenient. We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulations of slight but useful variations, given to him by the hand of Nature. But natural selection, as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts as the works of nature are to those of art."

There has been considerable hysterical writing in regard to the brutality of the struggle for existence which has been read into and superimposed on Darwin's original conception. "I [Darwin] should premise that I use this term in a larger and metamorphical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. Two canine animals, in time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant in the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on moisture. A plant which actually produces a thousand seeds of which only one can manage to come to maturity may truly be said to struggle with the plants of the same and other kinds which already clothe the ground. The mistletoe is dependent on the apple, and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for if too many of these parasites grow on the same tree, it languishes and dies. But several seedling mistletoes, growing close together in the same branch, may more truly be said to struggle with each other. As the mistletoe is disseminated by birds, its existence depends on them, and it may metaphorically be said to struggle with other fruit-bearing plants, in tempting the birds to devour and thus disseminate its seeds. In these several senses, which pass into each other, I use for convenience' sake, the general term 'Struggle for Existence.' "

In these extracts in Darwin's own words, we have his methods of interpreting changes in living things. Though he was one of the most abused men of the past century, he lived to see many turn to his views. At the close of the century *The Outlook* held a contest for the greatest book written from 1800 to 1900 and Darwin's *Origin of Species* received the largest number of votes as being the book that has had the greatest influence in molding the thought of the century.

The original conceptions of Lamarck and Darwin have been variously modified with the progress of science and new schools of neo-Lamarckians and neo-Darwinians have arisen, each holding in a modified form the original hypothesis of Larmarck and Darwin. There are other theories of evolution and it will be strange if more are not formulated in the future. Living protoplasm is so variable, plastic and adaptive that it is difficult to formulate a theory that explains all the conditions. Possibly if the theory did explain all of the conditions it would be as Jordan suggests, no longer philosophy, but science.

CHAPTER XVII

VARIATION—HEREDITY

LABORATORY SUGGESTIONS.—Every plant and animal studied during the course furnishes material for the study of variation. All that is necessary is to collect a large number of specimens and select some definite character for critical study. An interesting and valuable period on heredity can be given to working out the similarities and differences of the several members of the class between their parents and themselves, their brothers and sisters, etc., selecting such characters as hair color, eye color, stature, complexion, temperament, etc.

VARIATION

Definition.—"For though on the whole the offspring is like the parent or parents, its form is perhaps never identical with theirs but generally differs from it perceptibly and sometimes materially. To this phenomenon, namely, the occurrence of differences between the structures, the instincts, or other elements which compose the mechanism of the offspring, and those which were proper to the parent, the name variation has been given." (Bateson.)

The following brief review of some common variations aims to establish (1) the fact of variation, and (2) the extent with some reference to the kinds. This is necessary because heredity is in large part a study of the inheritance of variation. No attempt is made to explain the causes of variation.

Variation in Paramecia.—Variations in protozoa have received considerable attention within the past ten years. Here a generation is produced in a day and unlimited numbers of pedigreed stock can be secured for study in a short time. These unicellular organisms have been characterized as essentially free germ cells upon which the environment is directly acting. Jennings finds that paramecia and other protozoa are made up of numerous races, differing minutely but constantly. "The individuals of any race vary much among themselves, but these differences are matters of growth and environment, and are not inherited. What is produced in reproduction depends on the fundamental constitution of the race, not on the peculiarities of the individual parent. The fundamental constitution of the race is resistant to all sorts of influences; it changes only in excessively rare instances, and for unknown cause; in a study of thousands of individuals of paramecium, through hundreds of

FIG. 196

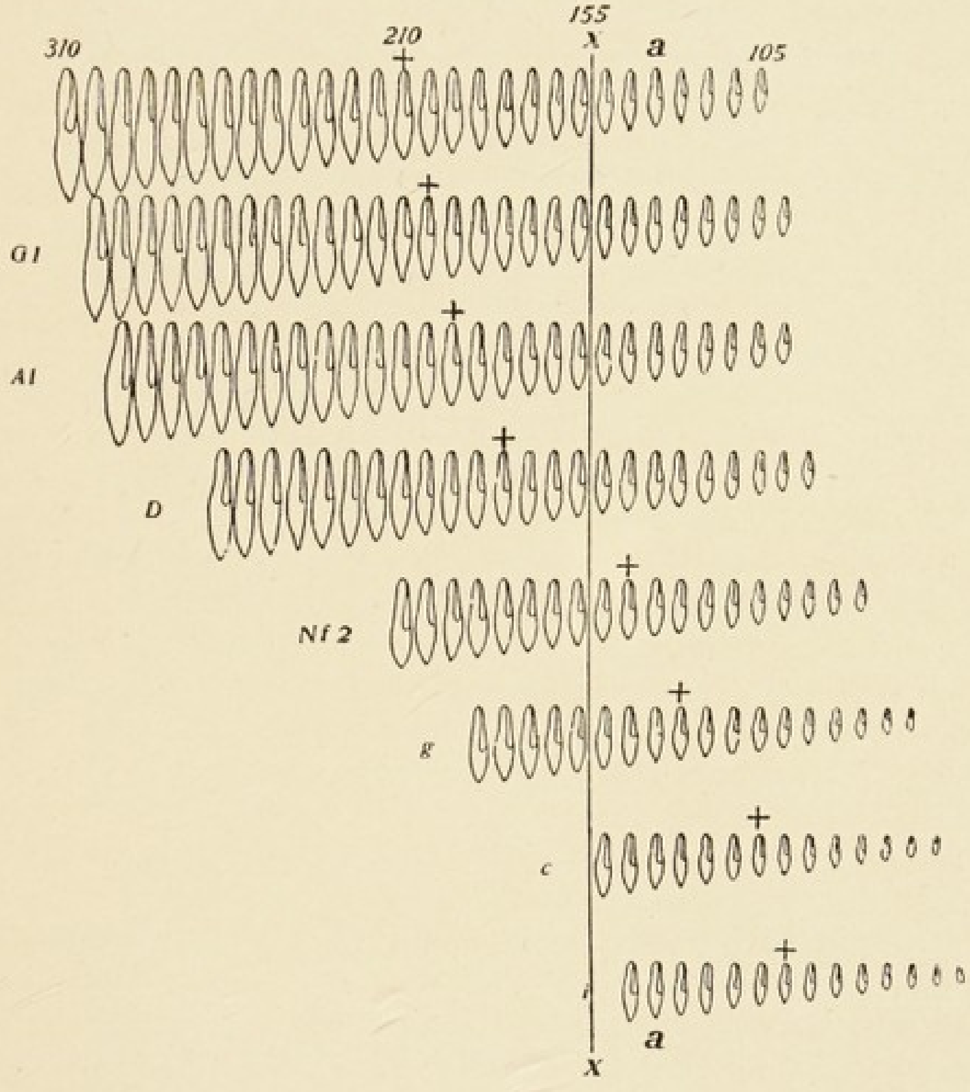


Diagram of the species of *Paramecium*, as made up of eight different races. Each horizontal row represents a single race. The individual showing the mean size in each race is indicated by a cross placed above it. The mean of the entire lot is shown at x, x. The numbers show the measurements in microns. The magnification is about 43 diameters. (Jennings.)

generations, hardly a single case of such change was observed. Most differences between individuals are purely temporary and without significance in inheritance; the others are permanent diversities between constant races. Systematic and continued selection is without effect in a pure race, and in a mixture of races its effect consists in isolating the existing races, not in producing anything new." (Jennings.)

Variation in Earthworms.—Pearl has studied 487 earthworms and finds that the range of somites is from 79 to 174 with an average of 142.71 somites, the percentage of variation being 8.31 per cent. The total length of the body ranged from 11.25 to 28.75 cm., giving a percentage of variation of 16.05 per cent. The length of the earthworm does not depend on the number of somites. In 495 individuals the number of somites anterior to the clitellum was from 29 to 32, or 1.41 per cent. variation. The number of somites in the clitellum was from 6 to 8, or 8.02 per cent. variation. With an increase in the number of somites in front of the clitellum, there is a marked tendency for the number in the clitellum to decrease.

Variation in Crayfish.—Variations in the crayfish have been extensively studied by Pearl, who made measurements of the length and breadth of the cephalothorax and of the several joints in the walking appendages. The cephalothorax from the tip of the rostrum to the posterior margin on the dorsal median line ranged from 19.2 mm. to 27.2 mm. in the 283 individuals measured. The head breadth ranged from 6.3 mm. to 15.3 mm. There were 50 of the 283 individuals that had a cephalothorax 24.7 mm. long; and 58 individuals that had a head breadth of an average of 10.7 mm.

The length of the three distal joints of the first three legs (cheliped and the first two walking legs) was measured. The length of the big claw joint ranged from 12.1 mm. to 34.1 mm., with 37 individuals averaging 19.6 mm.

The joint next to this one varied from 4.7 mm. to 11.5 mm., with 49 individuals averaging 6.95 mm.

The third joint from the end varied 6.9 mm. to 14.9 mm., with 55 individuals averaging 9.65 mm.

The first walking leg compared with this claw gives the following data: Distal joint, 4.9 mm. to 10.3 mm., with 46 individuals averaging 6.95; second joint, 3.4 mm. to 7.2 mm., with 40 individuals averaging 4.9 mm. Third joint, 5.5 mm. to 11.5 mm., with 49 individuals averaging 7.7 mm.

Sufficient of Pearl's results are given to indicate a considerable range of variation. In the discussion of the paper some of the following important conclusions are formulated:

1. A relatively high degree of morphological differentiation and specialization has associated with it a relatively high degree of variability in the parts concerned.

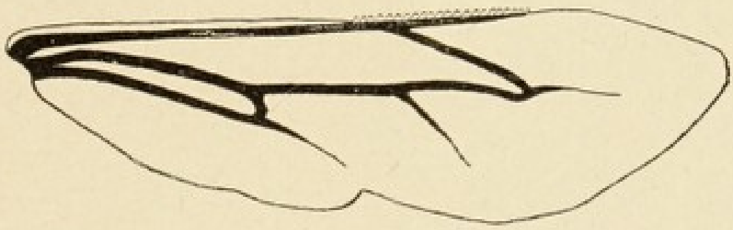
2. There is no reasonable doubt that the differentiated, specialized condition of the leg bearing the great chela is phylogenetically a relatively late acquisition. In other words it is not a primitive morphological condition. But we find that this part which has been modified most recently phylogenetically is also the most variable of the three appendages studied.

3. The correlation between the homologous segments of the two legs is higher when these two legs belong to contiguous metameres than when they are separated by an intervening metamere.

In all of these illustrations there is (1) a large amount of variation; (2) the variation is continuous and moves in both directions from the normal, *i. e.*, the normal length of the big claw is 14.6 mm., but there are a number of individuals with longer and shorter claws.

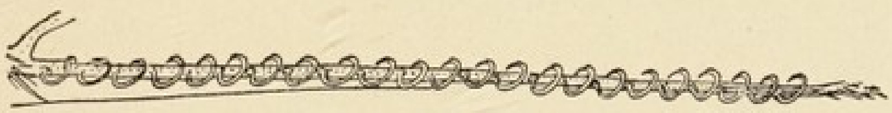
Variation in Insects.—This class of animals has been extensively studied. The method and results of these studies are illustrated by the following: On the second pair of wings of the worker and drone honey bee are found a number of hooks (Figs. 197 and 198). A study

Fig. 197



Hind wing of honey bee to show position of hooks. (Casteel and Phillips.)

Fig. 198



Part of the costal margin of hind wing of honey bee much magnified to show hooks. (Kellogg and Bell.)

of the hooks in six selected lots of drones and three lots of workers is shown in the following table. The number of hooks is shown at the top and the number of individuals at the bottom (Casteel and Phillips).

HOOKS ON HIND WING

Drones

	12	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Average,
I				4	4	8	11	9	4	6	1	1	2			21.56
II		2	1	12	21	23	20	17	2	2						20.12
III				1	7	12	15	28	14	14	6	2	1			22.09
IV			4	10	17	22	27	12	2	5	1					20.33
V				4	2	11	10	9	7	1	4	1		1		21.54
VI	1			3	3	7	6	23	23	19	6	6	1		1	22.42
	1	2	5	34	54	83	89	98	52	47	18	10	4	1	1	

Workers

	12	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Average.
I					6	9	12	11	6	5	1					21.42
II			4	13	42	74	94	61	45	11	4	2				21.08
III			2	11	18	18	33	8	6	4						20.37
			6	24	66	101	139	80	57	20	5	2				

Variation in Number of Tibial Spines of Melanoplus Femur-rubrum (Red-legged Locust).—The locusts or grasshoppers are insects with incomplete metamorphosis, the just-hatched young resembling the adults in all important structural characters, except for the absence of wings. The larval and adult legs are identical structures. On

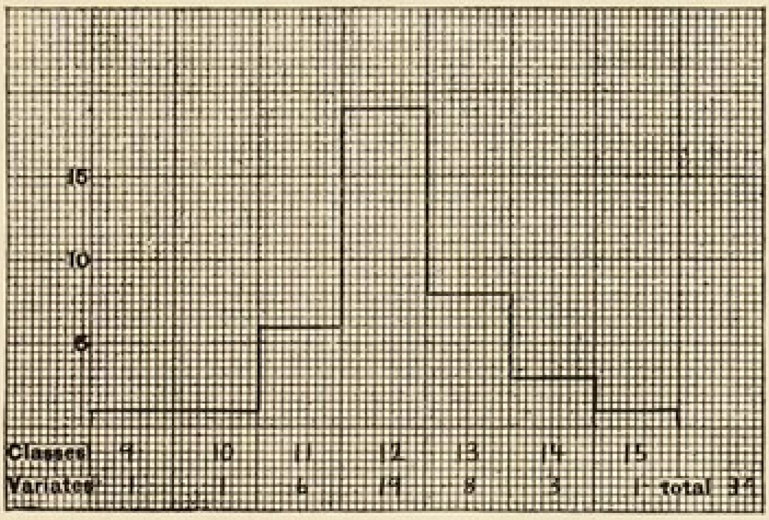
Fig. 199

The red-legged locust, *Melanoplus femur-rubrum*, and enlarged hind tibia showing inner (*i*) and outer (*o*) rows of spines. (Kellogg and Bell.)

the ventral (hinder aspect) of the tibiæ of the large posterior leaping legs are two rows or series of small but distinct spines, one along the outer edge, the other along the inner (Fig. 199). The number of spines in this series has been used as a diagnostic character of the various species of the large genus melanoplus.

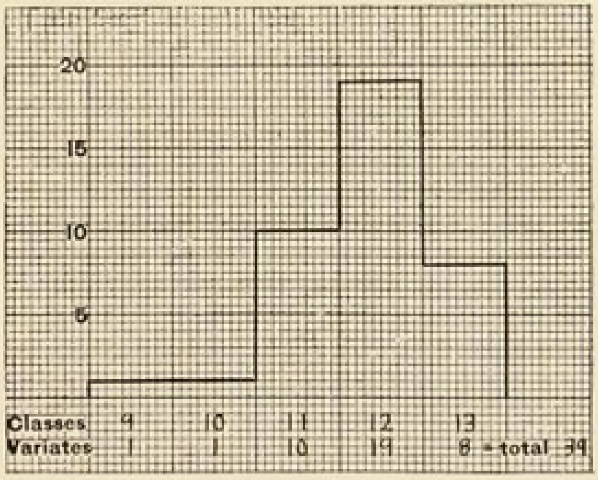
A lot of 89 adult individuals (50 females, 39 males) of the red-legged locust, *Melanoplus femur-rubrum*, collected at Ithaca, New York, in a brief time period, was examined to determine the variation in number of the tibial spines on the hind legs. The range and frequency of this variation is shown in the following frequency polygons:

FIG. 200



Frequency polygon of the variation in number of spines in the outer row of the right tibiæ in 39 male red-legged locusts, *Melanoplus femur-rubrum*. (Kellogg and Bell.)

FIG. 201

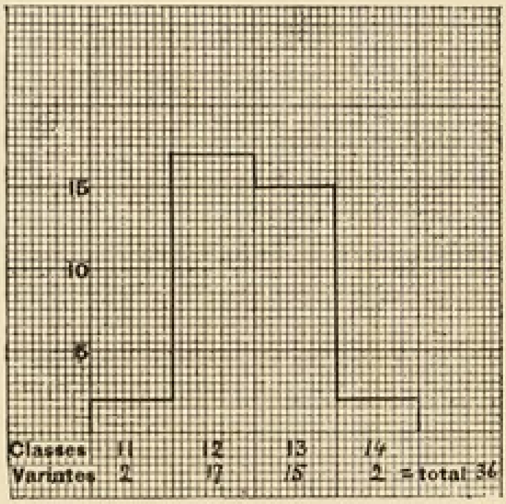


Frequency polygon of the variation in number of the spines of the outer row on the left side of 39 male red-legged locusts, *Melanoplus femur-rubrum*. (Kellogg and Bell.)

From these polygons it will be noted that the range is, in outer row, right tibia, males 9 to 15, females 11 to 15; left tibia, males

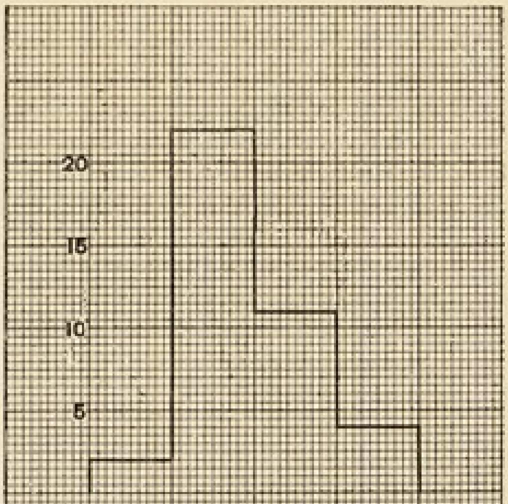
9 to 13, females 10 to 14; in inner row, right tibia, males 11 to 14, females 10 to 14; left tibia, males 11 to 14, females 12 to 16. The

Fig. 202



Frequency polygon of the variation in number of the spines in the inner row on the right tibiæ of 36 male red-legged locusts, *Melanoplus femur-rubrum*. (Kellogg and Bell.)

Fig. 203



Frequency polygon of the variation in number of the spines in the inner row of the left tibiæ of 39 male red-legged locusts, *Melanoplus femur-rubrum*. (Kellogg and Bell.)

mode for the outer row in both males and females is 12, for the inner row 12, with 13 nearly as frequent. Although the series are too short to afford fair conclusions from statistics, it is obvious that the frequency and range of the numbers of spines above the mode are larger than those below the mode, indicating the course of evolutionary movement (Kellogg and Bell).

Variation in Ranunculus.—A study of 337 plants of *Ranunculus bulbosus* which normally has 5 petals gives the following:

5 — 6 — 7 — 8 — 9, number of petals.
312 — 17 — 4 — 2 — 2, number of plants.

Here the variation is in one direction that tends to increase the number of petals.

Variation in Trillium.—The common trillium shows a great deal of variation and conspicuously illustrates how the sepals and petals may revert to a leaf-like form.

The flower stem in 233 plants varied in length from 0 to 340 mm.; average length, 91.52 mm.

Size of sepal—largest, 44 × 78 mm.
Size of sepal—smallest, 9 × 34 mm.
Size of petal—largest, 46 × 80 mm.
Size of petal—smallest, 8 × 26 mm.

The length of the filament which supports the anther is from 1 mm. to 34 mm., while the ovary has a stalk from 23 mm. to 5 mm. Here the several parts show a marked tendency to revert to the primitive leaf form.

Variation in General.—There are other forms of variation than the ones given above, but these serve to show that variations are generally present in organic life. When one attempts to classify variations as to their cause, the problem is difficult and perplexing. An illustration or two will serve to make this point clearer. The tendency for the parts of the flower in trillium to take on a leaf-like shape and color is explained on the one hand as due entirely to environment and of little significance; while others claim that the variation is caused by the condition of the germ-plasm and as such is bound to occur and is largely independent of environment. It is well known that school children that have better care are slightly taller than those that come from a slum district. When each reaches maturity, will the well fed be taller and will the cause be due to extrinsic or intrinsic factors?

Methods of Studying Variation.—The accurate study of variation selects a character which can be accurately measured or counted;

and the results of such a computation for a large number of individuals is represented in a table or curve (Figs. 199 and 203). These curves serve at a glance to indicate the extent of the variation, whether it is continuous or discontinuous, and the direction in which the variation is moving. Different values are worked out by using certain mathematical formulæ which is an attempt to express accurately the extent and significance of variation. This method has given rise to the "biometrician" school whose exact work has done much to clear up the indefiniteness of biological description. There are many biologists, however, who hold that living protoplasm cannot be measured in millimeters and that a measurement only partly describes. Much skill is required in selecting the so-called characters in the study of variation. At present there is a vast amount of data that has been collected in variation that helps to a better understanding of living protoplasm.

Fig. 204

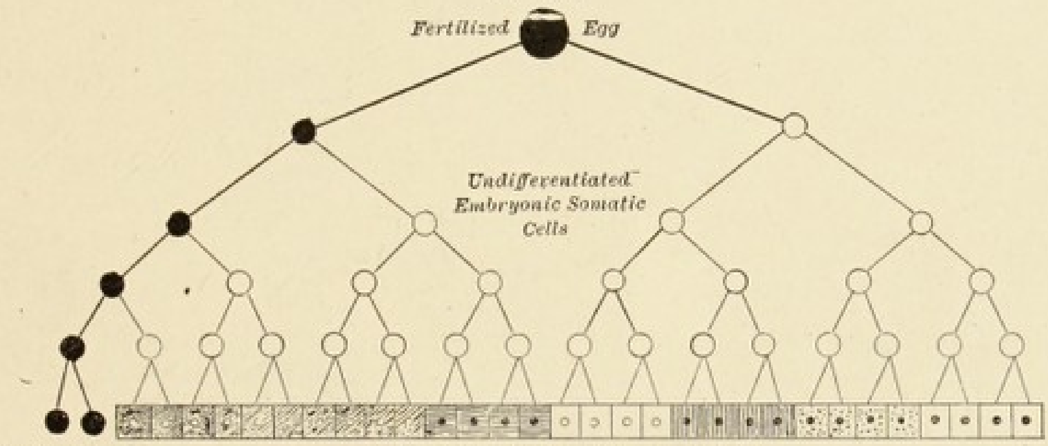
"Half-curve" representing the number of "petals" on 416 flowers of the marsh marigold (*Caltha palustris*). (From Doncaster, after De Vries.)

HEREDITY

Scientists are continually aiming to discover the method of heredity. Is the secret to be learned from a study of the evidences of heredity such as are everywhere found in adult and growing organisms (variation), or in the detailed relations that exist between the chromosomes in fertilization? This question serves to show the two main avenues through which the problem of heredity has been and is being studied. It may as well be admitted now as later that science does not understand just how characteristics are transmitted from ancestor to offspring.

Heredity is everywhere present in organic life and serves to transmit not only useful likenesses but many that never mature or are rudimentary. The great comparative anatomist Wiedersheim has found 180 vestigial organs in man alone. No system of organs is free from them, the skeleton, the muscles, the nervous, the digestive systems; all have structures that are important to some of the lower vertebrates. The vestigial structures serve to illustrate the hold that heredity seems to have on living matter. Someone has characterized heredity as "organic memory," but this is only suggestive, for mammalian organisms are reproducing with remarkable fidelity ancient ancestral structures of the Devonian geological period which extends back in time beyond the reckoning of man. The formation of an embryonic notochord and of gill-slits illustrates this point. Heredity can thus be relied upon to produce ancestral structures both good and bad, a fact of organic life always to be reckoned with.

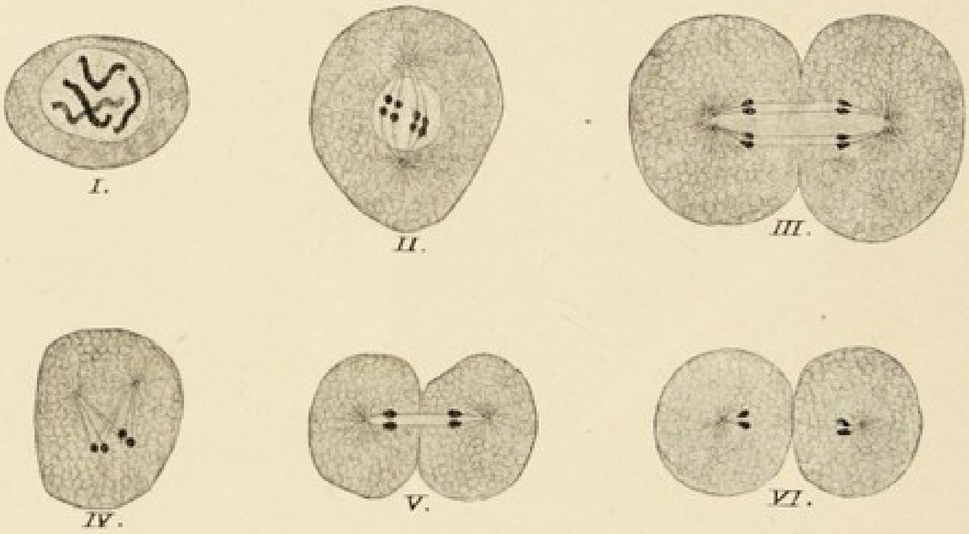
Fig. 205



Schema of germ and somatic cell differentiation. (After Klebs.)

Heredity and the Cell.—Whatever may be the ultimate analysis of the problem of heredity, there can be no hesitation in stating that the transmitted characters exist potentially in the protoplasm of the cell. From the egg of a robin only a robin will develop, from the ovum of an oak only an oak will grow, and during growth each follows its own successive embryological stages even to the minutest details. It has been well said "nature never yet made two eggs or two sperms exactly alike." The cells which give rise to new organisms are the germ cells, sperms, and ova. These differ greatly in shape and size—some of the sperm cells being but $\frac{1}{1000000}$ the bulk of the ovum and yet the paternal characters are easily recognized in the adult. As has already been explained (pages 67 and 115) the egg cell passes through a period of preparation for fertilization which is known as maturation. During these changes the chromatin undergoes a rearrangement which results in both a qualitative and quantitative elimination of chromatin. The sperm cell during growth undergoes a similar distribution of the chromatin. Fertilization is the union of the male chromatin (chromosomes) and the female chromatin, but it is readily understood that the repeating of this process generation after generation would serve to accumulate not only a large amount but a vast number of individual chromosomes were it not for this preparatory reduction in maturation. The number of chromosomes in the developing cells of an organism is the same as those of each parent and not double the number. This means that the paternal and maternal chromosomes fuse which

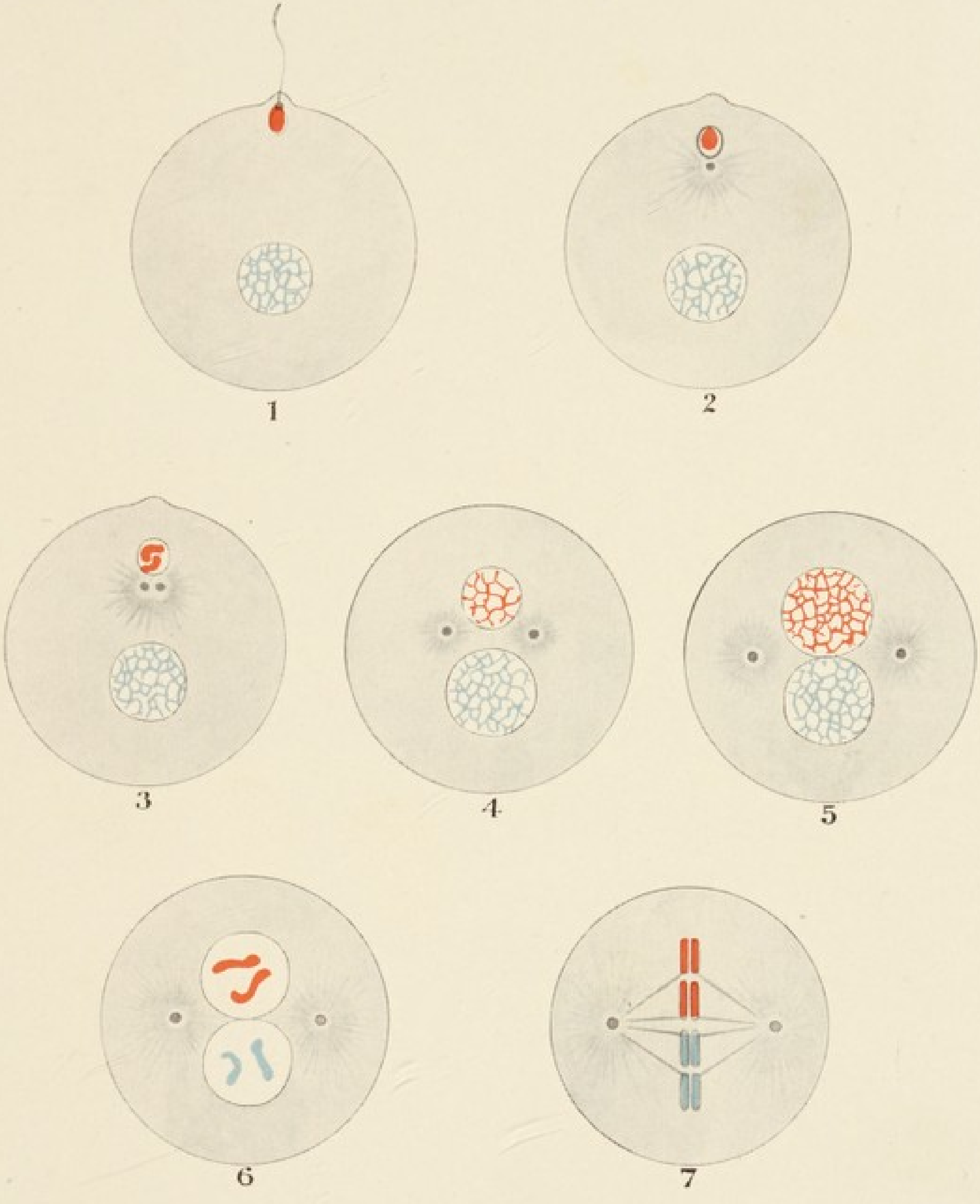
FIG. 206



The stages of spermatogenesis in *Ascaris megalocephala bivalens*: *I*, spermatogonium, with four chromosomes (the normal number for the cells of this species); *II*, primary spermatocyte with two *tetrads; III*, primary spermatocyte undergoing division into two secondary spermatocytes, each with two *dyads; IV*, secondary spermatocyte; *V*, secondary spermatocyte undergoing division into two spermatozoa, each with two *monads; VI*, two young spermatozoa, each bearing two monads—chromosomes. (After A. Brauer.)

is the essential part of fertilization. The number of chromosomes or even the particles of chromatin are relatively small as compared with the number of structural and physiological characteristics of an organism; so that we may not assign to each of these bodies the exclusive responsibility of reproducing a given adult character. The present idea is rather that each chromosome is a complex body which contains a number of "determiners" (hypothetical bodies) which have the potential power under appropriate conditions of causing the developing cells to take on a given form. This does not mean that the chromosome or the germ cell is a miniature adult that simply unfolds but rather that the initial or determining cause

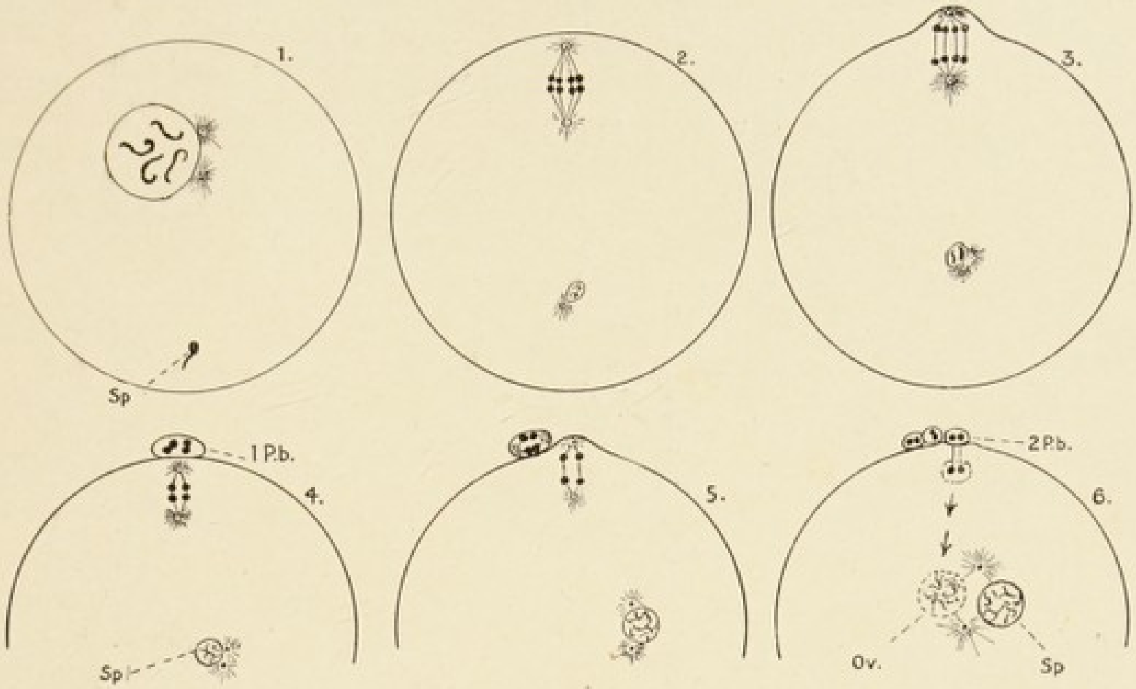
PLATE XI



Fertilization. (After Adami.)

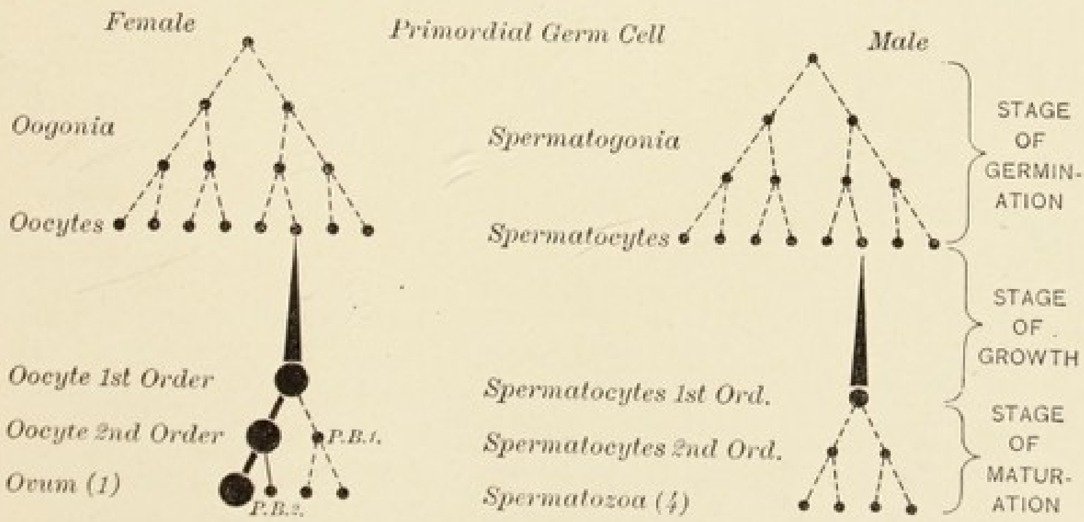
1. Entry of spermatozoön into ovum. 2. Loss of tail of spermatozoön. 3. Division of centrosome. 4 and 5. Chromatin both of ovum and spermatozoön converted into a network; the two moieties gain approximately equal size. 6. Chromatin of both becomes arranged into chromosomes (one-half of the number of each variety that is usual in the body cells of the species). 7. Formation of spindle; division of chromosomes; partition of chromosomes derived from the two parents in equal number between the two future cells (blastomeres).

Fig. 207



The stages of reduction in the ovum and formation of polar bodies. Diagram based upon Boveri's observations on the maturation of the ovum of *Ascaris megalocephala bivalens*. 1, entrance of spermatozoon, *sp.*, into ovum; 2, formation of two tetrads in place of four chromosomes; 3, first division—formation of two pairs of dyads; 4, expulsion of first polar body (1 *P.b.*) containing two dyads; 5, second division of nucleus of ovum, and division of nucleus of first polar body—formation in each of two pairs of monads; 6, expulsion of second polar body and division of first polar body—ovum and each polar body provided with two monads. The arrows, pointing to *Ov.*, indicate subsequent enlargement of the nucleus of ovum and conversion of the two monads into a chromatin network similar to that developed in *Sp.*, the nucleus of the spermatozoön. (After Adami.)

Fig. 208



Schema of comparative descent of ovum and spermatozoa. The dotted lines indicate successive cell generation, the continuous lines connect successive stages of one cell. (Modified from Boveri.)

is in the germ cell and that the full expression of characters comes through a continuous series of developmental stages which is determined by the condition of the determiners in the fertilized egg cell. The cells of the body are divided into body-plasm or soma and the germ-plasm. Weismann restricted the germ-plasm to the nucleus of germ cells, but the term is coming now to refer to the

Fig. 209

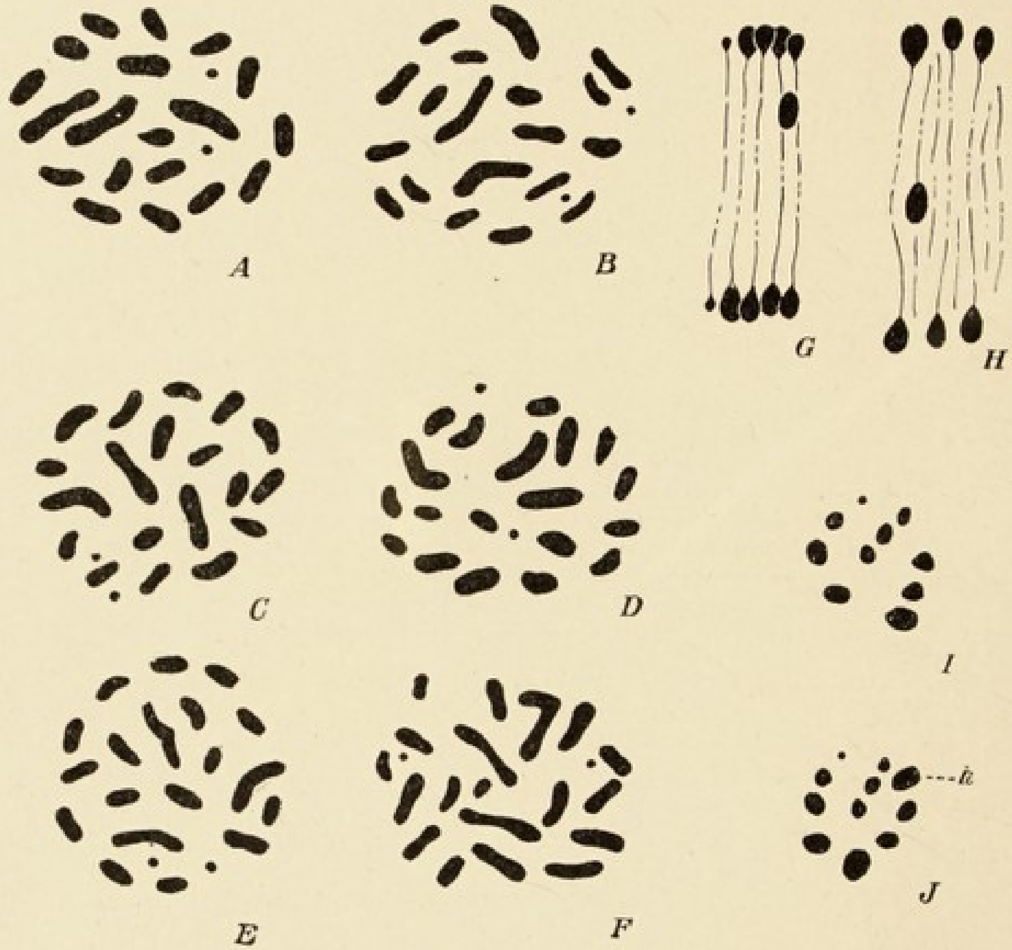


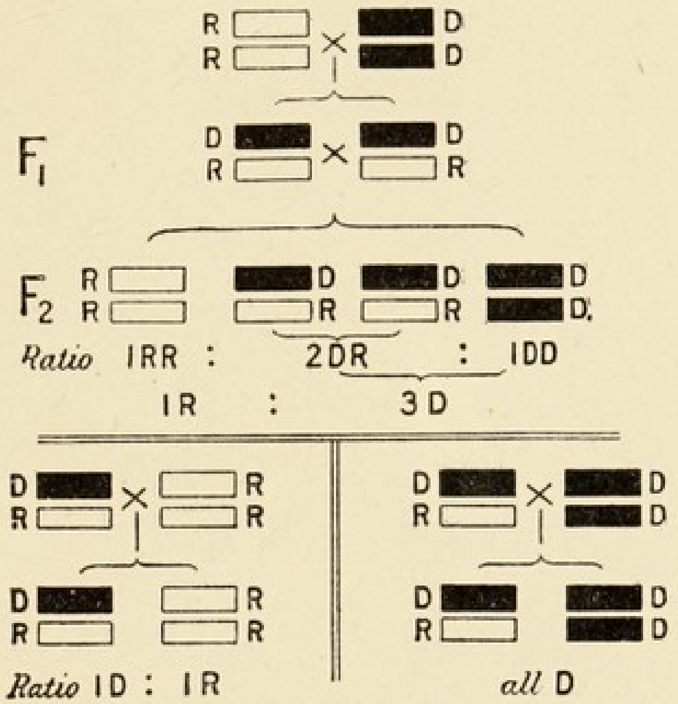
Figure to show variation in shape and size of the chromosomes. *Anasa tristis.* *A* to *F*, spermatogonial groups; *G*, *H*, anaphases of second division, showing division of *m*-chromosomes in *G*, and the undivided heterotropic chromosome on both spindles; *I*, *J*, anaphase groups from the same spindle, polar view, second division, showing *m*-chromosome and macrochromosome in each and the heterotropic (*h*) in *J*. (After Le Fevre and McGill, in Biological Bulletin.)

whole of the germ cell. In this more liberal use of the term germ-plasm the determiners are not exclusively confined to the chromatin but are found in all parts of the germ cells. After the germ-plasm has given rise to an individual, some of it is left behind which participates in the formation of new offspring, and as Davenport phrases it "there really is no inheritance from parent to child, but parent and child resemble each other because they are derived from the same germ-plasm, they are chips from the same old block; and the son is the half-brother to his father, by another mother."

Mendelism.—The Augustine monk, Gregor Johann Mendel, published in 1865 the results of his studies on the pedigree culture of peas in which he announced an important theory of heredity. This is summarized by Professor Castle as follows:

FIG. 210

A

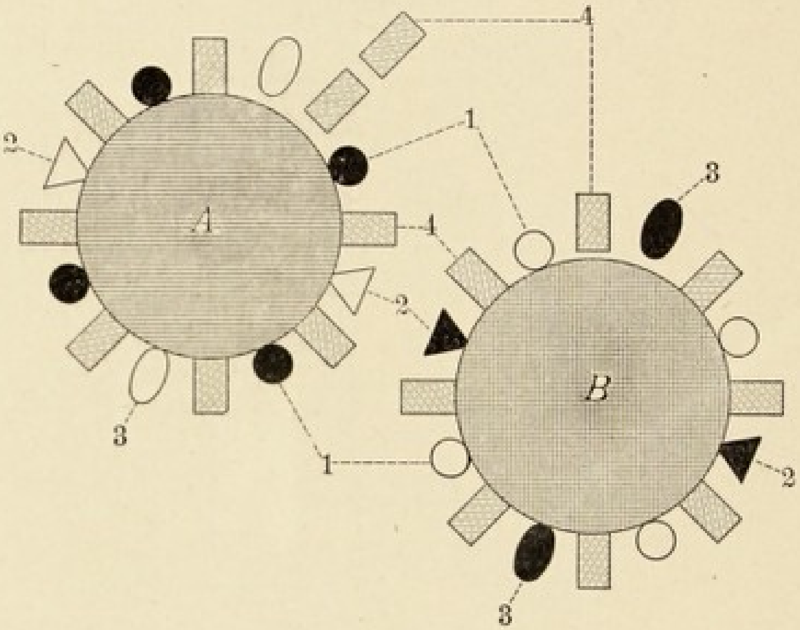


B *C*

Schema of Mendel's law for a single pair of "antagonistic" properties. *A*, the results of hybridization of a pure dominant (D) with a pure recessive (R) form; *B*, the results of crossing a hybrid with a recessive form: 50 per cent. of progeny pure recessive, 50 per cent. hybrid (but apparently dominant); *C*, the result of crossing a hybrid with a dominant form: all apparently dominant (but 50 per cent. pure, 50 hybrid. (Bateson.)

"1. The Law of Dominance. When mating occurs between two animals or plants differing in some character, the offspring frequently all exhibit the character of one parent only, in which case that character is said to be 'dominant.' Thus, when white mice are crossed with gray mice, all the offspring are gray, that color character being dominant. The character which is not seen in the immediate offspring is called 'recessive,' for though unseen it is still present in the young. White, in the instance given, is the recessive character. The principle of heredity just stated may be called the law of dominance. The first instance of it discovered by Mendel, related to the cotyledon-color in peas obtained by crossing different garden varieties. Yellow color of cotyledons was found to be dominant over green; likewise, round smooth form of seed was found to be dominant over angular wrinkled form; and violet color of blossoms over white color.

Fig. 211



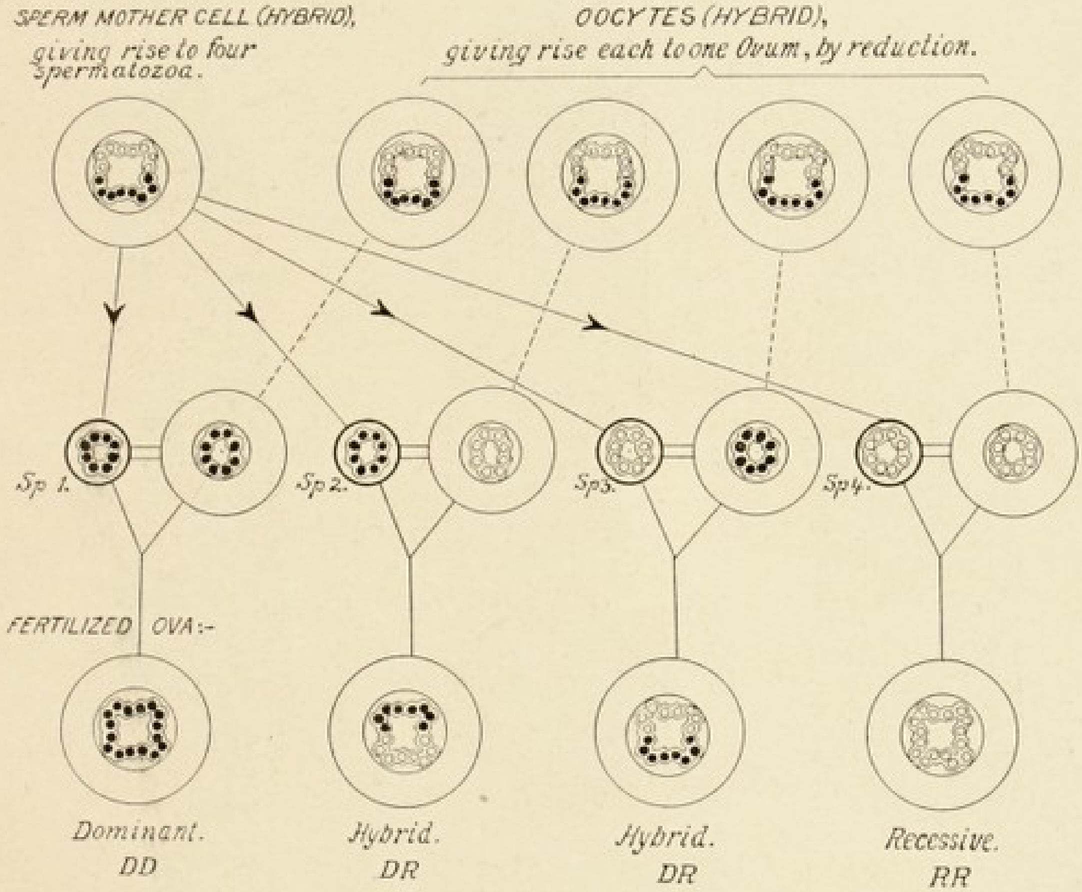
Schema of mode of interaction of two biophoric molecules in a common cell sap. *A*, of maternal; *B*, of paternal origin. 1, 2, 3, allelomorphic side-chains, which, when liberated into the cell sap, will be attracted to the biophore exercising the strongest affinity; 4, side-chains common to both molecules, built up indifferently into either. (After Adami.)

"2. Peculiar hybrid forms. The law of dominance is not of universal applicability; Mendel does not so declare, though some of his critics have thus interpreted him. In many cases the cross-bred offspring possess a character intermediate between those of the parents. This Mendel found to be true when varieties of peas differing in height were crossed.

"Again, the cross-breds may possess what appears to be an intensification of the character of one parent, as when in crossing dwarf with tall peas the hybrid plant is taller than either parent, or as when, in crossing a brown-seeded with a white-seeded variety of bean, the offspring bear beans of a darker brown than that of the brown-seeded parent.

"3. The cross-bred may have a character entirely different from that of either parent. Thus a cross between spotted, black and white mice, and albino mice, produces commonly mice entirely gray in color, like the house-mouse. Again, in crossing beans, a variety having yellowish-brown seeds crossed with a white-seeded variety yields sometimes black mottled seed, a character possessed by neither parent.

Fig. 212



Schema to illustrate Mendel's law regarding the second hybrid generation as regards a single pair of features; as also to illustrate the effects of reduction of the chromosomes in oögenesis and spermatogenesis. Each germ cell (first row) is originally provided with chromosomes of paternal (black) and of maternal origin (white). The existence of the law demands that in the process of reduction the ovum and the spermatozoön (second row) become provided with chromosomes and biophores) that are either of paternal or of maternal descent, but not of both; although, as above noted, the biophores may in their growth and development have attracted side-chains formed primarily by the opposed order of biophores, to the exclusion of those originally belonging to them. (After Adami.)

"These three conditions may be grouped together by saying—the hybrid often possesses a character of its own, instead of the pure character of one parent, as is true in cases of complete dominance. The hybrid character may approximate that of one parent or the other, or it may be different from both. There is no way of predicting what the hybrid character in a given cross will be. It can be determined only by experiment, but it is always the same for the same cross, provided the parents are pure. Often the hybrid form resembles a supposed ancestral condition, in which case it is commonly designated a reversion. Illustrations are the gray hybrid

Fig. 213

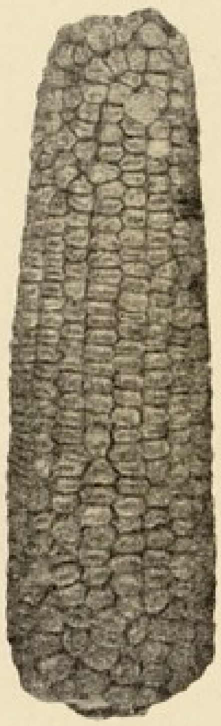


Fig. 214

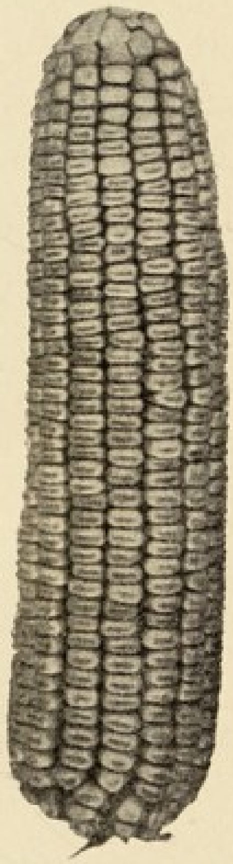
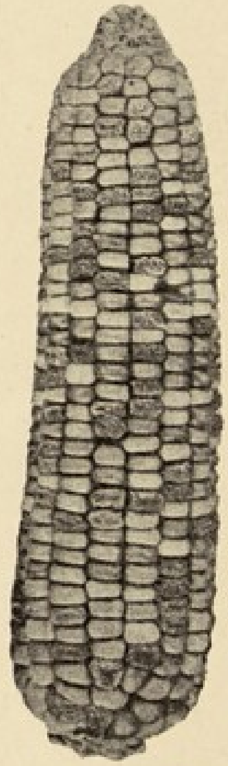


Fig. 215

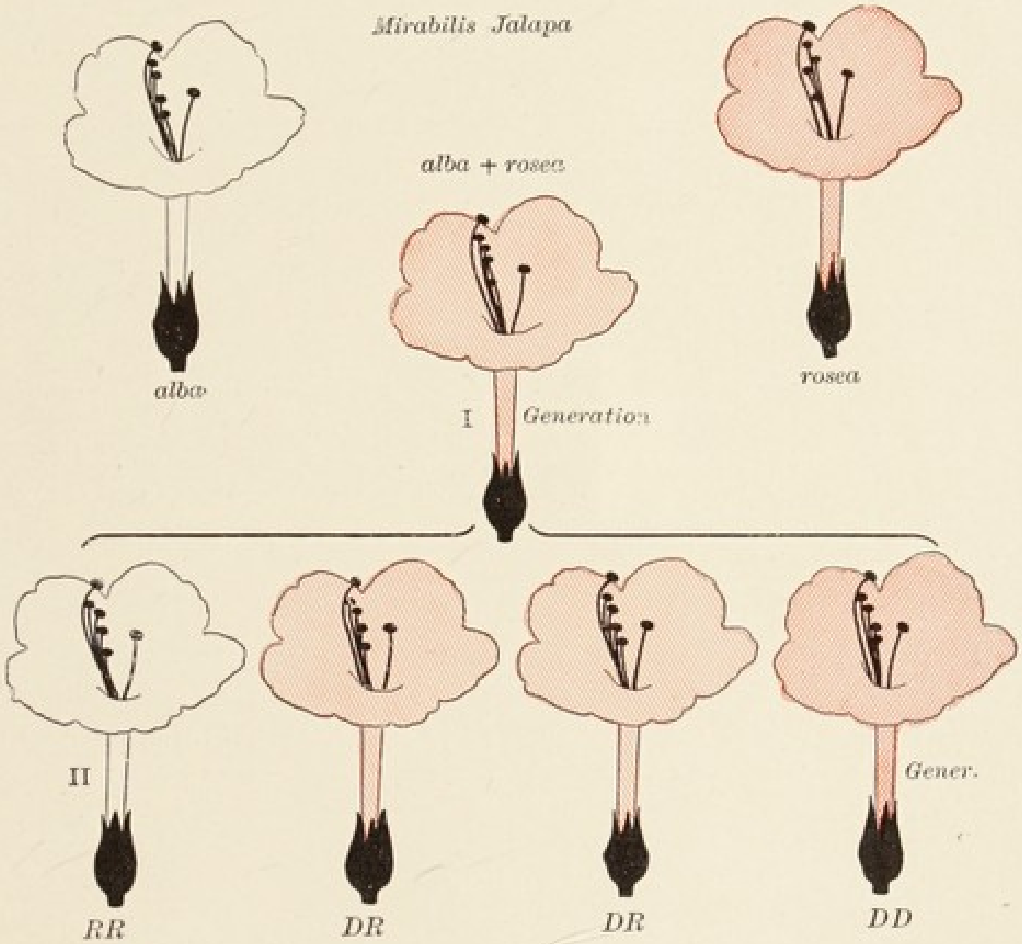


Figs. 213, 214, and 215, showing Mendelian inheritance in maize. Fig. 213, pure sweet parent race; Fig. 214, pure dent parent race; Fig. 215, ear bearing F_2 progeny kernels from the cross of Figs. 213 with 214. The ears bearing F_1 progeny kernels are indistinguishable in appearance from the pure dent parent ears (Fig. 214). In general, it may be said, that the F_1 kernels resemble most closely the dent parent in their chemical characters. In other words, there is a definite tendency toward the complete dominance of the chemical conditions found in the dent parent over those found in the sweet parent. This dominance is by no means perfect in all characters, however. In particular, the F_1 kernels are plainly intermediate between the two parents in respect to sugar content. The F_1 kernels in these experiments are not to be told by visual examination from the pure dent parent, yet a chemical analysis shows that they really are different. (Pearl and Bartlett.)

mice, which are indistinguishable in appearance from the house-mouse, and slate-colored pigeons resulting from crossing white with buff pigeons.

"4. Purity of the germ-cells. The great discovery of Mendel is this: The hybrid, whatever its own character, produces ripe

PLATE XII



Mirabilis Jalapa
alba + rosea
alba
rosea
I
Generation
II
Gener.
RR
DR
DR
DD

germ-cells which bear only the pure character of one parent or the other. Thus, when one parent has the character A, and the other the character B, the hybrid will have the character AB, or in cases of simple dominance, A (B). The parenthesis is used to indicate a recessive character not visible in the individual or B (A). But whatever the character of the hybrid may be, its germ-cells, when mature, will bear either the character A or the character B, but not both; and As and Bs will be produced in equal numbers. This perfectly simple principle is known as the law of 'segregation,' or the law of the 'purity of the germ-cells.'"

The unit characters which are now generally recognized have in some cases a general distribution in the organism. "Tall and dwarf habits are diffuse characters of the plant, as a whole. Hairiness may be on stem, leaves, calyx, part or all of them. Mendelian hereditary units are not leaves, petioles, stamens, etc., but qualities of these organs or still more diffuse qualities of the whole plant." (Harper.) In the same sense human stature, temperamental vigor, or resistance to disease are unit characters that are inherited and are qualities which are a part of the whole body. Heredity is to be looked on as determining the character of the cells, as those in the skin or muscles; and as formulating the qualities of the organism as a whole; for example, it is a dog with all of the dog characteristics.

According to the cytologists, heredity means the normal combination of the chromosomes, although some are willing to admit that the rest of the cell may play an important part. The more deeply one studies into the problem, the more difficult it becomes to formulate a definite hypothesis. The recognition that characters behave as units in heredity has served to add a new avenue of study with the result that breeders in particular are able to select more successfully than ever before the characters that they wish to emphasize. But the whole story is not so simple for some of the unit characters are associated in pairs, as it were; and some of the characters, like skin color, for example, are now known to depend upon a number of determiners.

"There are, however, instances in which it appears that Mendelian segregation may not be perfect. It has been maintained that an instance of this is provided by hair-length in guinea-pigs. When a long-haired ('Angora') guinea-pig is mated with a short-haired, the F_1 offspring are short-haired; shortness being dominant, owing perhaps to the presence of a factor which prevents the growth of

Fig. 216

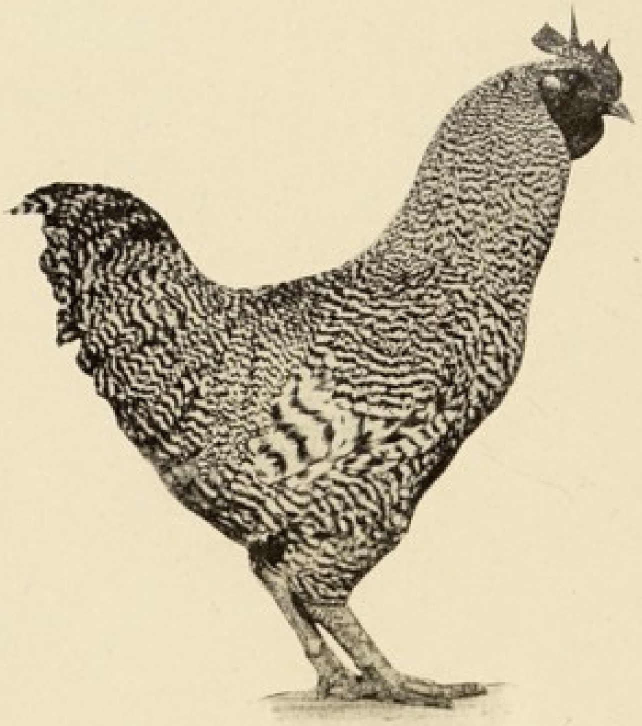


Fig 217

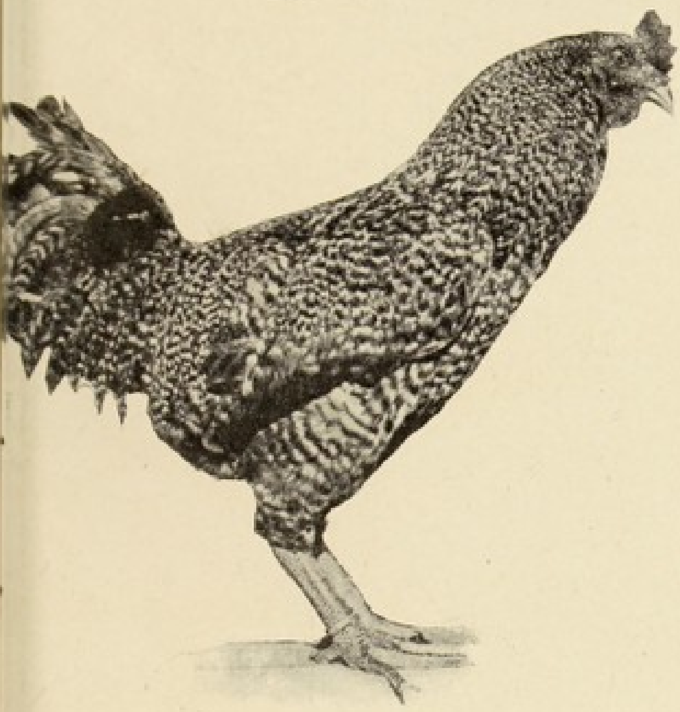
Pure bred barred Plymouth Rock. ♂ Pure bred Cornish Indian game. ♀
If one mates the cross-barred Plymouth Rocks ♂ × Cornish Indian game ♀ he gets only barred birds. (Pearl and Surface.)

Fig. 218

Fig. 219

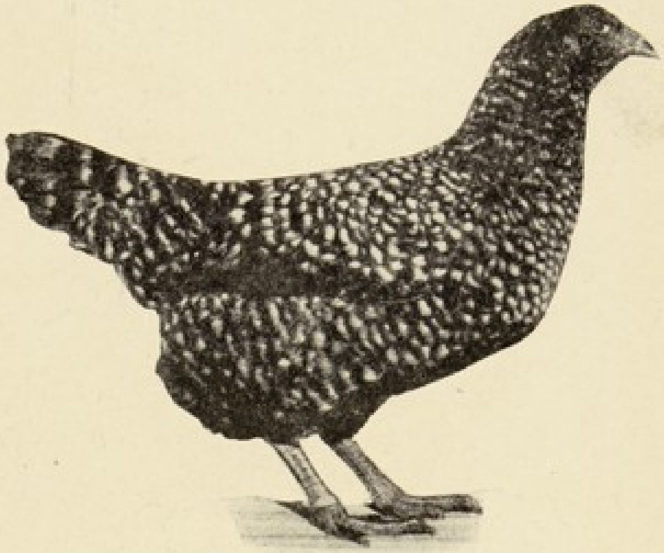
Pure bred Cornish Indian game. ♂ Pure bred barred Plymouth Rock. ♀
If one mates Cornish Indian game ♀ × with barred Plymouth Rock, all the male offspring will be barred and the female will be black. (Pearl and Surface.)

Fig. 220



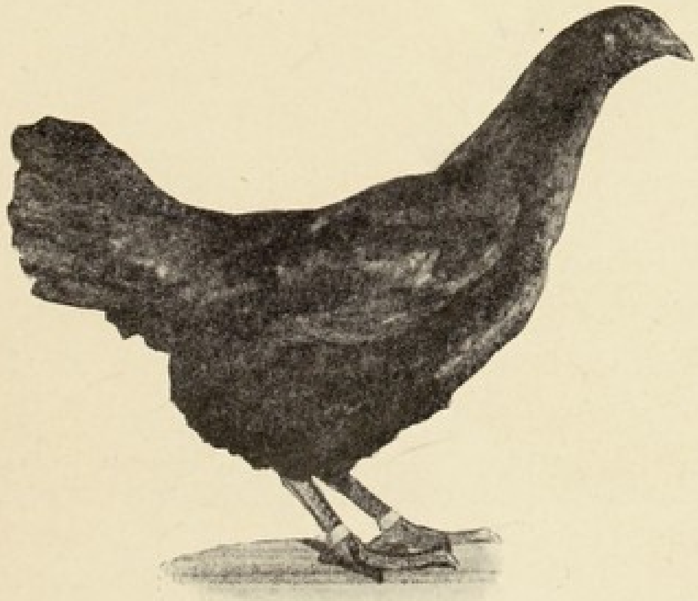
Barred F_1 hybrid ♂

Fig. 221



Barred F_1 hybrid ♀

Fig. 222

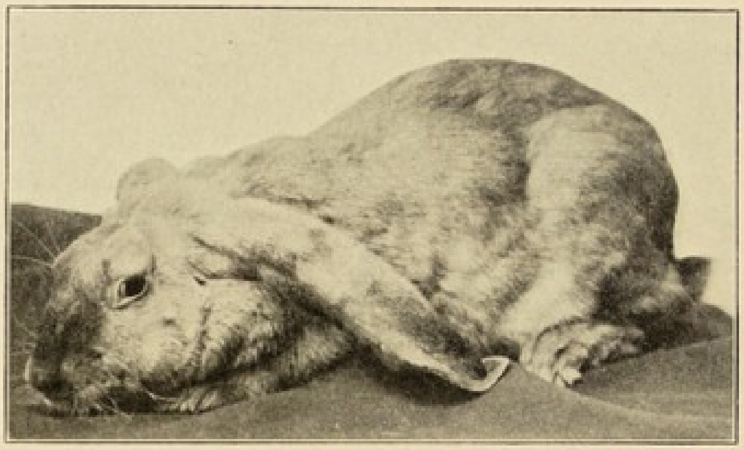


Non-barred (solid black) F_1 hybrid. ♀

Figs. 216 to 222 show that barring of the feathers is inherited in a sex-limited fashion. The barred pattern is inherited as a unit character and there is no evidence of a blended inheritance of degrees of intensity of pigmentation. No more striking evidence of the segregation and particulate behavior of characters as units in inheritance can be found anywhere. (Pearl and Surface.)

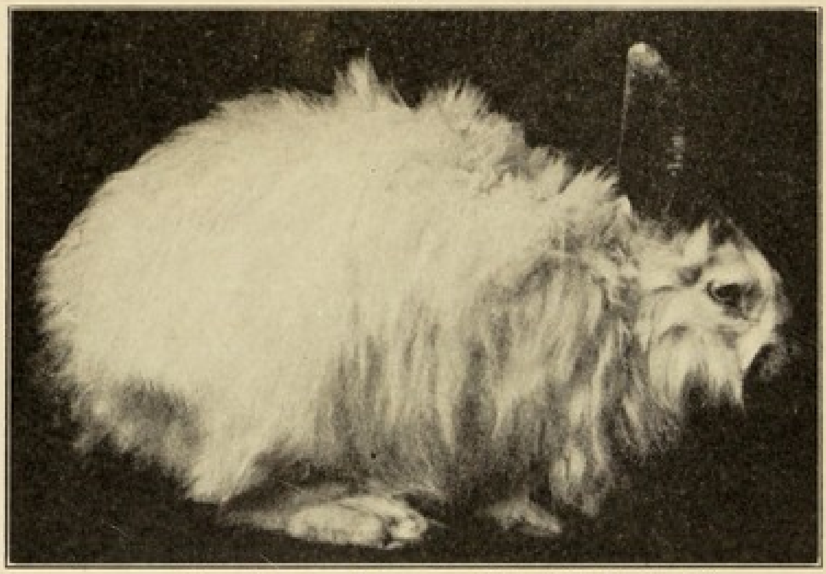
the hair after reaching a certain length. But when such F_1 (heterozygous) short-hairs were mated together, in addition to apparently pure longs and shorts, animals with hair of intermediate length were produced, and these crossed back with pure long-hairs gave no short-haired young. It is suggested that the long and short

Fig. 223



A brown-coated lop-eared rabbit, female. (W. E. Castle.)

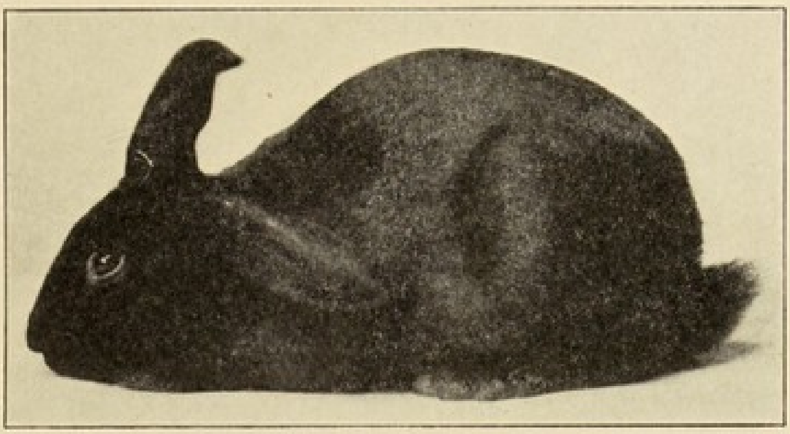
Fig. 224



An albino, short-eared Angora rabbit. (W. E. Castle.)

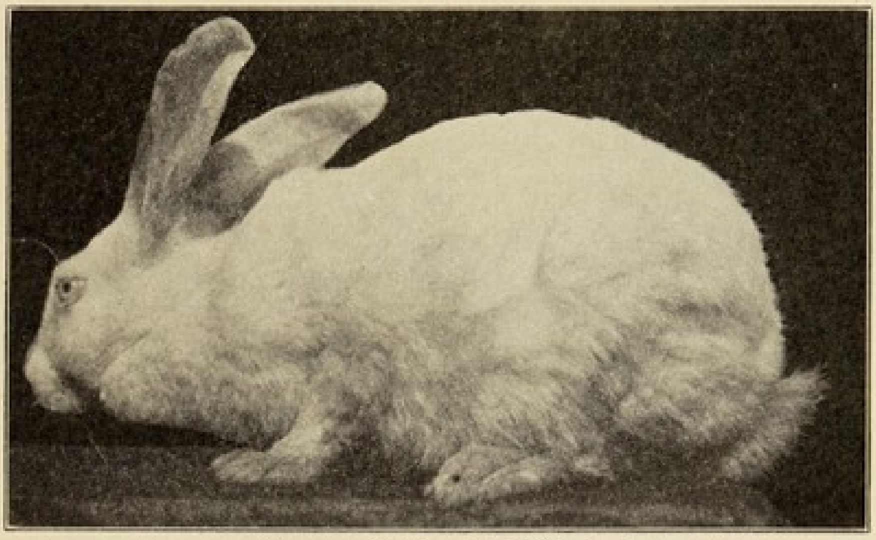
characters have become fused in some germ-cells, segregation being incomplete or non-existent, so that germ-cells bearing the mixed character are produced. Again, in a cross between lop-eared and short-eared rabbits, young with ears of intermediate length are produced, and these mated together give no evidence of segregation in the next generation. From these and some other similar observations it must be concluded, either that in some cases there is incomplete segregation or even complete fusion of alternative characters, or that what appear to be simple characters are really complex, and that the true-breeding intermediates are formed by a new combination of elementary factors." (Doncaster.)

Fig. 225



A black-coated, half-lop-eared rabbit, son of the two rabbits shown in Figs. 223 and 224 respectively. (W. E. Castle.)

Fig. 226



Albino rabbit F_2. (W. E. Castle.)

An illustration of the practical value of what may seem to some as an academic discussion is seen in the testing out of the theory of unit characters as follows: "Some valuable wheats are liable to the attacks of a fungus giving rise to the disease called 'rust,' other less valuable races are immune. Biffen has found that by crossing the two races together, fertilizing the hybrids (F_1) among themselves, and selecting the homozygous plants in the F_2 generation, wheat can be produced which combines the valuable features of

Fig. 227

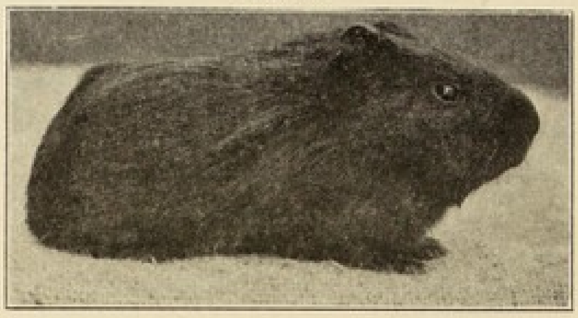


Fig. 228

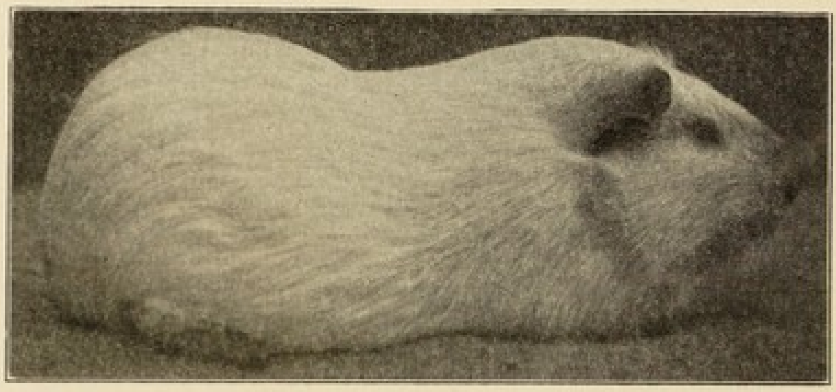
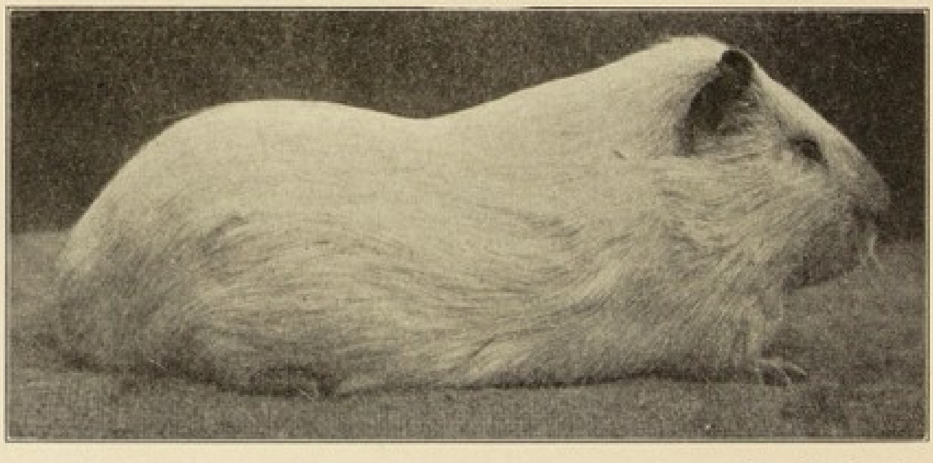


Fig. 229



Figs. 227 to 229.—Fig. 227, a young, black guinea-pig, about three weeks old. Ovaries taken from an animal like this were transplanted into the albino shown in Fig. 228. Fig. 228, an albino female guinea-pig. Its ovaries were removed and in their place were introduced ovaries from a black guinea-pig (Fig. 227). Fig. 229, an albino male guinea-pig, which was mated with the albino shown in Fig. 227. (Description and figures from W. E. Castle.)

one race with the immunity to rust of the other, and so a new and most useful variety of wheat is produced."

The tendency at present is to fix the attention upon some character and observe its behavior in heredity. Francis Galton first recognized that there is a tendency for certain characters of the parents to blend in the offspring while others are alternative. When

FIG. 230

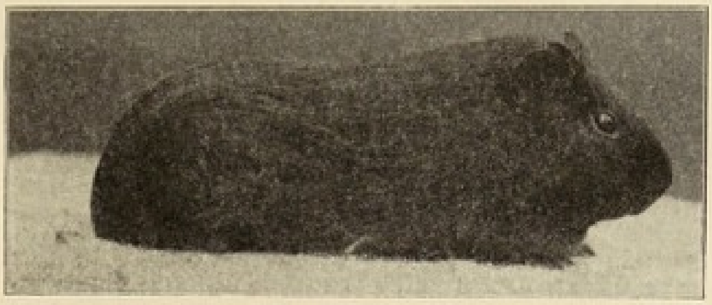


FIG. 231

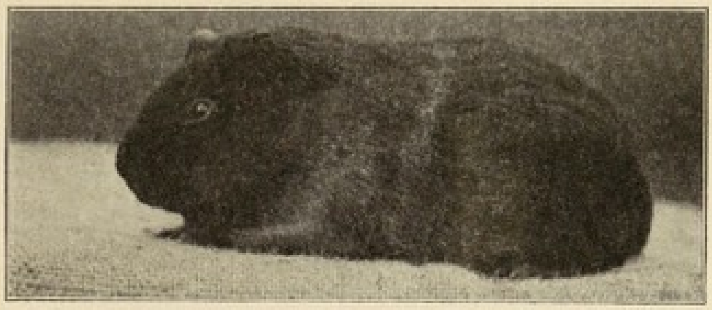
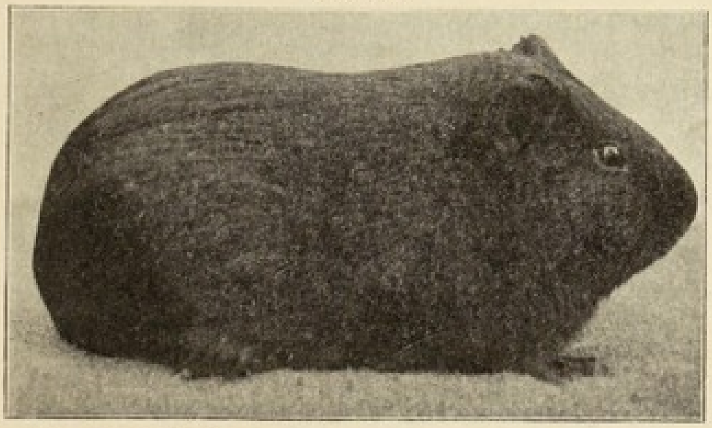


FIG. 232

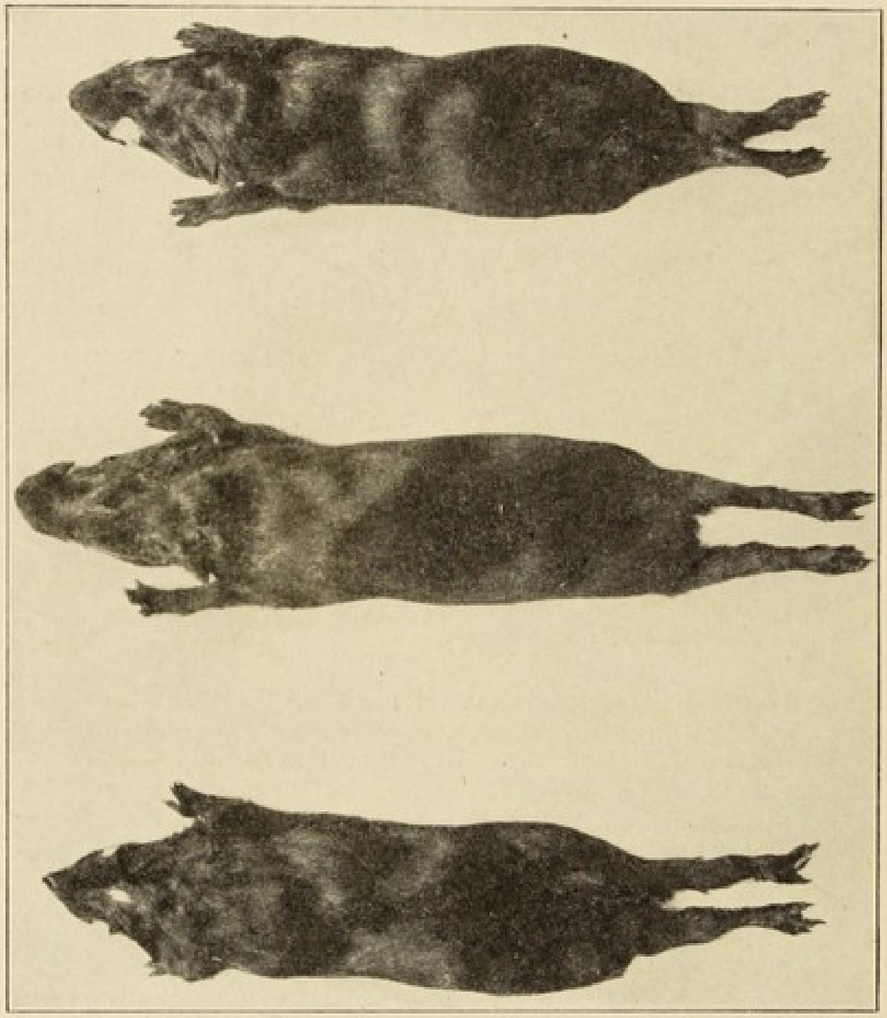


FIGS. 230, 231, 232 are pictures of three living guinea-pigs.

the brown-coated, lop-eared rabbit is crossed with an albino, short-eared angora rabbit, the offspring has ears of intermediate size, which sometimes stand erect and sometimes lop. The hair of the offspring (in the above cross) was short and black, the long white hair did not appear; but where these black hybrids were bred, the parental characters reappeared in their offspring in a definite proportion.

"The effect of crossing a pigmented rabbit with an albino is similar to that produced when two pieces of glass, one transparent, the other opaque, are held up together. We see only the opaque one. Never-

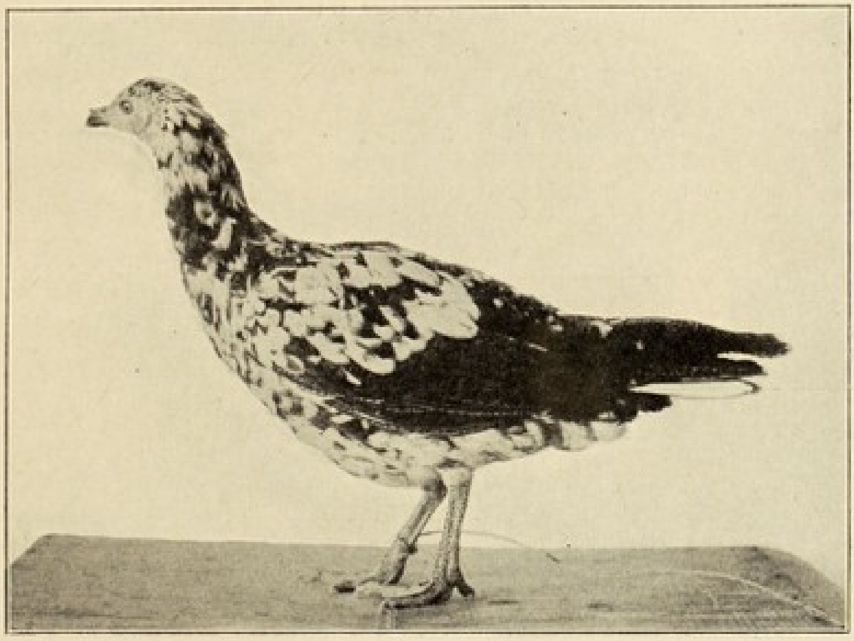
Fig. 233



The preserved skins of three guinea-pigs, all of which were produced by the pair of albinos in Figs. 228 and 229. From evidence such as this it is concluded that the inheritance cannot be affected by modifications of the body of the parent, not even when the body is completely changed, since the body so far as heredity is concerned is merely a container of the reproductive cells. To modify the inheritance we must modify the reproductive cells. (Description and figures from W. E. Castle.)

theless, the two conditions have not blended; each retains its original distinctness, and the two can be separated again at will (Fig. 226). So it is in the Belgian produced by cross-breeding with an albino. The albino character is there, though unseen, and will appear as a distinct entity when the cross-bred reproduces, for it will be represented in approximately half of the sex-cells formed by the cross-bred animals, the alternative or Belgian character being represented in the other half. It is as if the two pieces of glass, combined originally to illustrate the formation of a cross-bred animal, were separated again to illustrate the formation of the reproductive elements by the cross-bred, For every element formed having the opaque character, there will be another having the transparent character, but there will be no elements of an intermediate nature." (Castle.)

Fig. 234

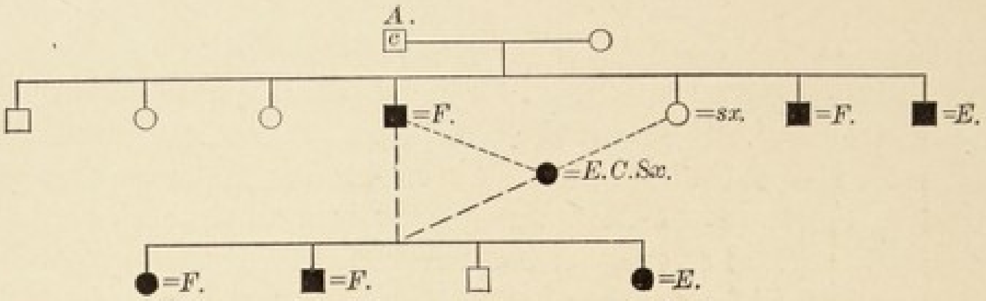


Hybrid fowl which is a cross between guinea hen and game-cock, showing in an interesting manner the distinctive color of both parents. This is a form of mosaic inheritance. (Bred and photographed by Dr. Raymond Pearl.)

For the discussion of latency, atavism, acquired characters, prepotency, origin of sex, and other equally important and interesting phases of heredity, the student is referred to the many elaborate works on heredity.

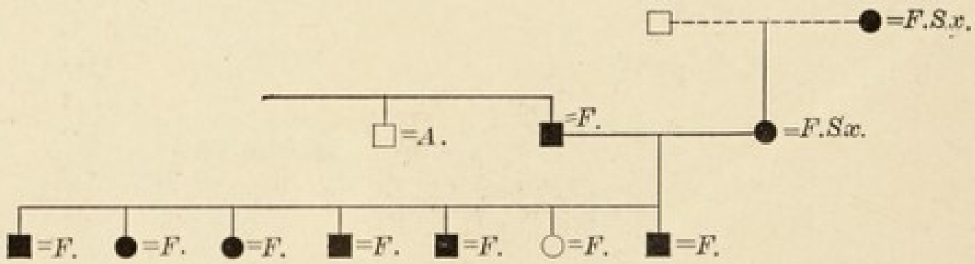
Heredity and Man.—No statement can be made about the laws of heredity in plants and animals that is not in a general sense applicable to man. It remains to be shown that all forms of inheritance follow the unit character law, which is being advocated by some of the present writers. At any rate it serves to clarify greatly the whole subject of inheritance. A great deal of attention is being given to the study of pedigrees of man and to noting in what proportion defects for example are handed on from generation to generation.

Fig. 235



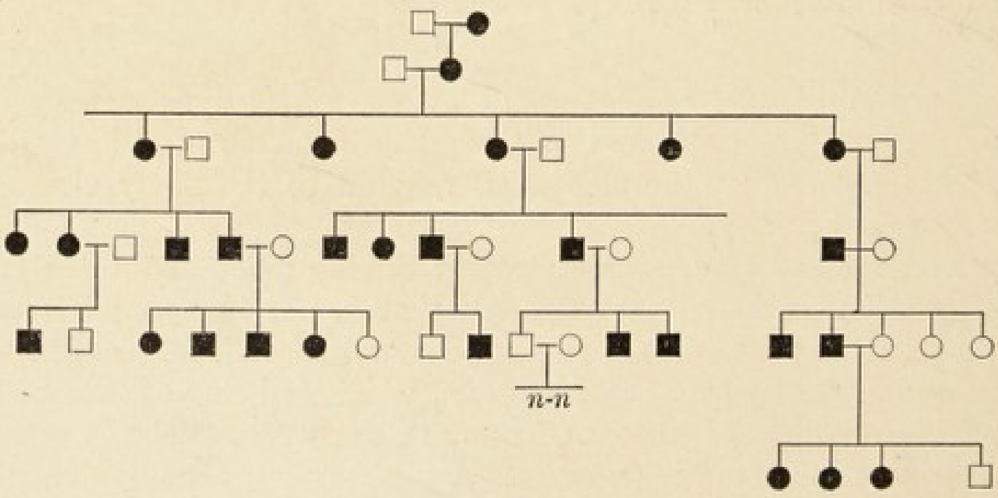
This chart illustrates the hovel source of defectives. A feeble-minded man had by his defective sister an epileptic daughter with criminal instincts; then by this daughter he had four children, two feeble-minded, one epileptic, and the fourth an anencephalic monster who died directly after birth. The empty germ-plasm yields only emptiness. These things were done in a little hut in the woods until it burned down and now mother and eldest daughter, when not in the county jail or the Monmouth County Almshouse, live in a cellar in town. The man is dead, but some of his protoplasm are living and at large. (Case 3165.—Davenport and Weeks.) *A* = alcoholic; *c*, criminal; *E*, epileptic; *F*, feeble-minded; *Sx*, unchaste.

Fig. 236



This chart illustrates again the product of two feeble-minded parents. The father belongs to a fair strain except that his brother also is alcoholic. The mother, like her mother in turn, is immoral. There are seven children, of whom six are known. One of these is an epileptic at State Village and all of the others are feeble-minded. After the father's death the mother had an illegitimate child who died in infancy, and she is now married to a feeble-minded and alcoholic man who is the younger brother of her daughter's feeble-minded husband. (Case 3031.—Davenport and Weeks.)

Fig. 237



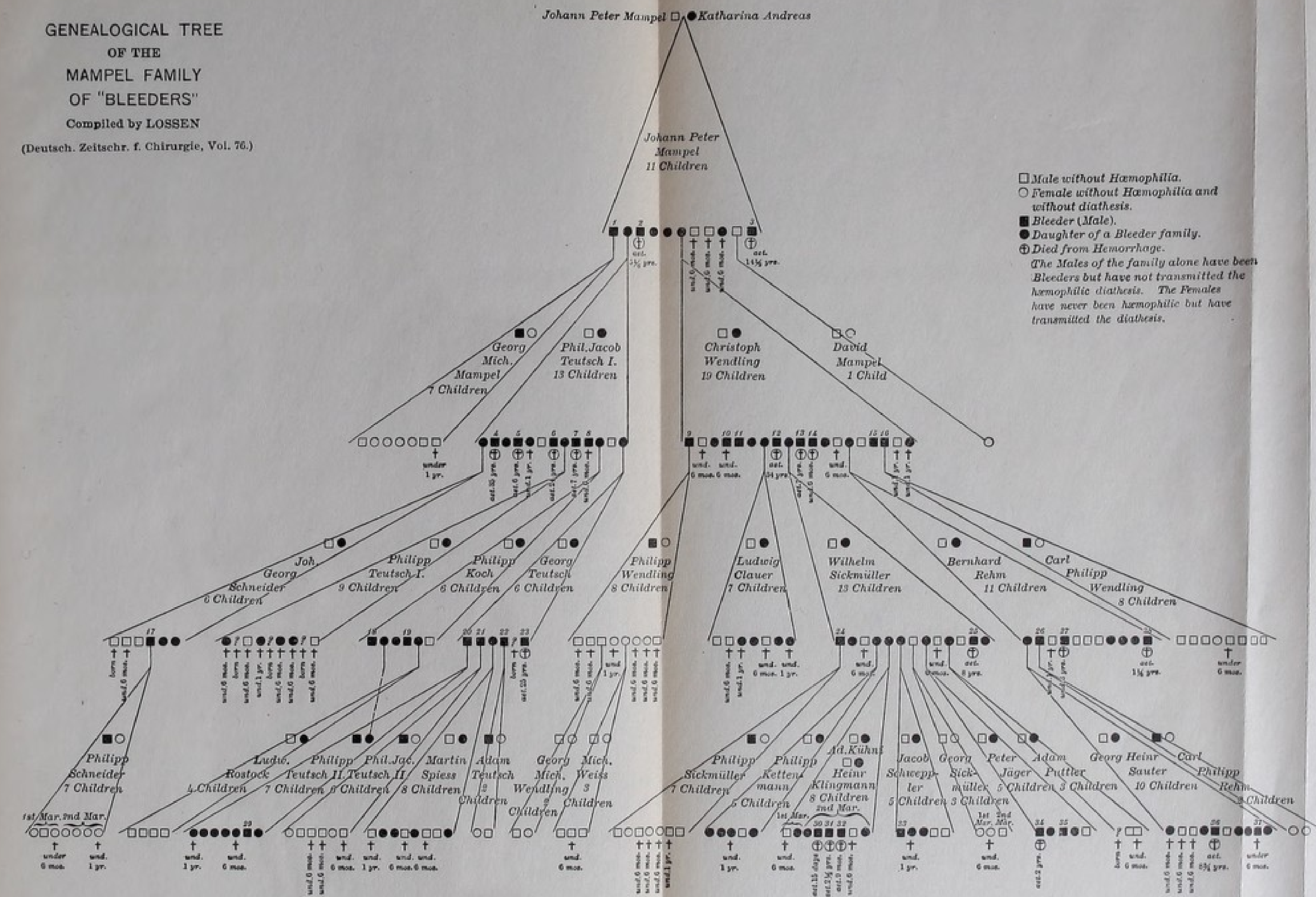
Pedigree of a family with poorly nourished nails and hair, the black symbols. (Nicolle et Halipre, from Davenport.)

PLATE XIII

GENEALOGICAL TREE OF THE MAMPEL FAMILY OF "BLEEDERS"

Compiled by LOSSEN

(Deutsch. Zeitschr. f. Chirurgie, Vol. 76.)



- □ Male without Hæmophilia.
- ○ Female without Hæmophilia and without diathesis.
- ■ Bleeder (Male).
- ● Daughter of a Bleeder family.
- ⊕ Died from Hemorrhage.

The Males of the family alone have been Bleeders but have not transmitted the hæmophilic diathesis. The Females have never been hæmophilic but have transmitted the diathesis.

The Kallikak Family.—The story of this family has been traced from the present back to Revolutionary days. The first Martin Kallikak (name fictitious) was of good English ancestry, but he took advantage of a feeble-minded girl with the result that she had a feeble-minded son. From this son there have been 480 descendants with the following history: 36 were illegitimate, 33 sexually immoral, 24 confirmed alcoholics, and 3 epileptics. Over 80 died in infancy, 8 kept houses of ill fame and 143 were feeble-minded. Forty-six of the 480 were found to be apparently normal.

The man who started this long line of delinquents married a Quaker girl after the Revolutionary War and from this legal union 496 descendants have been traced. There is no trace of feeble-mindedness and but 2 cases of insanity. None of the offspring has been criminal or ne'er-do-well.

The descendants of the same father and the normal and the defective mother have been studied as they lived in the city and country and the same marked descrepancy obtains. In the cities the legal descendants are lawyers, physicians, and respectable business men; while the others live in the slums. The same phraseology describes the differences between the two in the rural districts. Wealthy and influential farmers employ unknowingly their distant relatives who are shiftless and subsist by the aid of charity. (The Kallikak family, Goddard.)

Eugenics.—Eugenics is the term which describes the application of the laws of heredity to man, especially emphasizing the beneficial results of good mating. It has served to direct attention to the inheritance of defects as well as musical skill or scholarly interests. The results are summed up in Davenport's book on *Heredity in Relation to Eugenics.*

Much remains to be discovered concerning the exact method of heredity and the causes of variation, although sufficient is known to enable us to understand more clearly their relation to evolution and their importance to mankind. Variation and heredity are two terms used to describe kindred characteristics of living protoplasm which are always present where life exists. They are as fundamental as metabolism and like it understood only in part. Heredity and variation are not opposing characters but according to several writers variation is an expression of incomplete inheritance.

CHAPTER XVIII

ANIMAL BEHAVIOR AND ITS RELATION TO MIND

LABORATORY SUGGESTIONS. — A number of observations on the behavior of various types of animals are recorded in this chapter and serve a double purpose: (1) They are models of scientific description of animal responses; (2) they are to be studied just as the morphology of an animal is studied. In this connection the nature of the stimulus, the responses, the reactions to different stimuli, etc., are to be worked out. Two general questions arise in this study: (1) What kind of responses are common to all animals; to all vertebrates? (2) What changes are to be found in the behavior of animals that possess a well-defined cerebrum (*neencephalon* of Edinger)? If there is adequate time in the course, the various interpretations of animal behavior may be discussed as a part of the laboratory work.

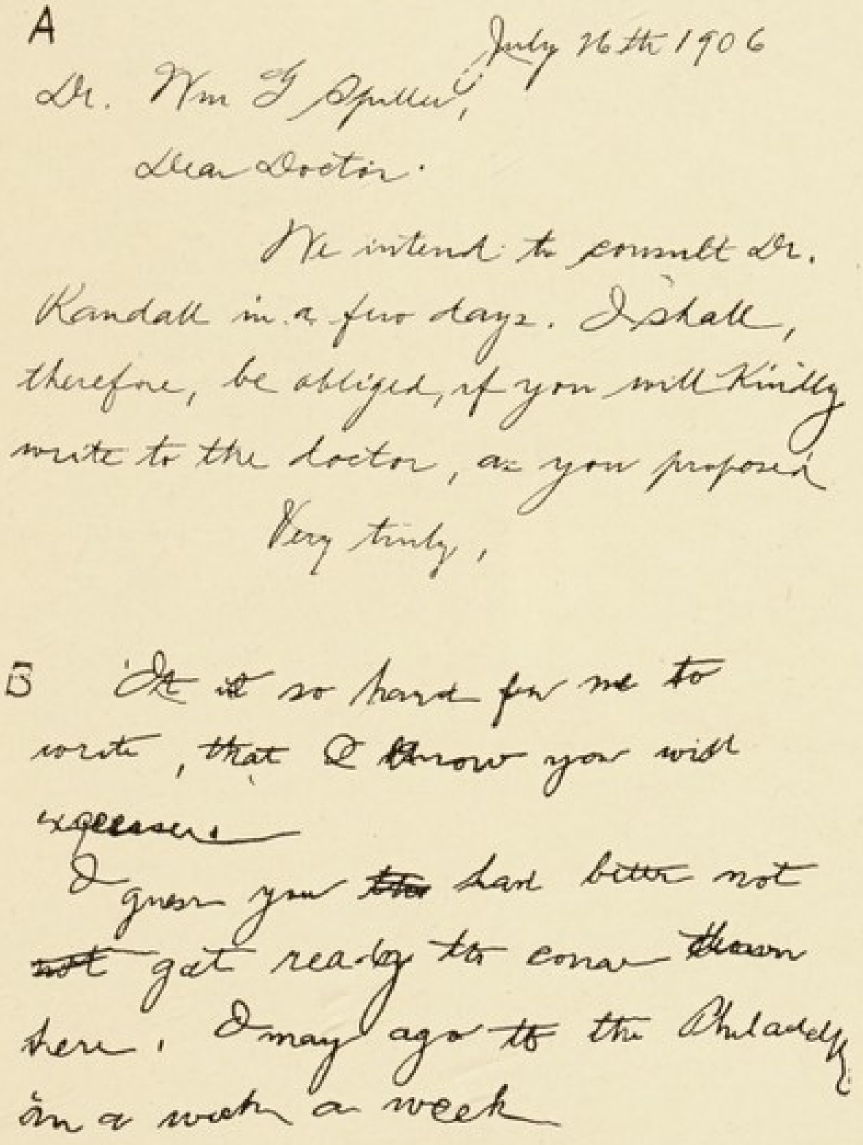
AN important phase of biology is the application of the theory of evolution to the general problem of animal behavior and the development of intelligence. As we have endeavored to emphasize, evolution implies genetic relationship. It is a very strange procedure that utilizes the theory of evolution to explain the development of the muscles, skin, skeleton, nervous system, etc., of animals and omits animal behavior. Just at present it seems best to use this rather ill-defined term "animal behavior" rather than mind for the varied expression of mentality among animals, because there is some difference of opinion as to the use of the word mind, and the term animal behavior enables us to approach the topic without prejudice.

We know sensations directly only in ourselves. Each individual is isolated from all other individuals and the nervous system of one gives out no material substance to another, therefore we are compelled to judge of the sensations of others by our own feelings or states. At the very outset of our consideration of animal behavior we are beset with our greatest difficulty, namely, how to judge and interpret the actions of animals, especially the simpler ones. We stand at one side and look on without being able to enter fully into their lives. We can never know directly how an animal feels or how an object looks to him. When we see an animal apparently in pain, we say that if we were acting that way, it would be because we were in pain, therefore the animal must be suffering. The possibility of wrong interpretation of this point is made clearer by the two following experiments. Take the common earthworm and cut it in two about in the middle. The posterior part writhes and twists, doubling itself up into various knots. The first time we see this effect, we may shudder in horror because the animal is suffering such pain. Is this the correct explanation? How does the anterior half act, the part that contains the largest ganglion of nervous matter in its body? This part moves off calmly, just as an earthworm normally moves, without any writhing. The anterior end would suffer as much pain as the posterior if there were no centralization of nerve cells to form a "brain," but given a "brain" it should suffer more. Structurally the "brain" is the place with which all the nerves are connected. To it, they report and from it commands issues; it has a steadying, regulating, and coördinating power. The anterior part of the worm is acting under supervision; the posterior half cannot coördinate its movements and so they become aimless and purposeless. The second illustration further emphasizes the care that must be exercised in interpreting animal activities. It has been a part of my work to chloroform a number of cats preparatory to a study of them in an advanced course in anatomy and the following has been a common experience: When three or four cats are placed in an air-tight box with the requisite amount of chloroform or ether, two or three of them will never utter a sound but quietly succumb to the anesthetic, while the remaining one or two will howl in a pitiful or angry fashion. If I had not had several in the box, all under the same conditions, I should have thought this most humane practice exceedingly cruel. Animals, like human beings, must be studied as individuals, for each has a certain range of activities. This range becomes wider as we ascend in the scale.

Some Biological Aspects of the Human Mind.—It is a common-place in our experience that mental processes are always associated with the nervous system. To the nervous system is assigned the work of correlating not only mental activities, but many other forms of activity in the several organ systems. It appears that the central nervous system is well organized and that certain regions take charge of given activities. This is well illustrated in the experiments already described for the frog. When the frog was decapitated and an irritant in the form of acetic acid was applied to the skin, the hind legs and often the fore legs moved in a definite fashion, with the result that the moistened filter paper soaked in acid was brushed off. If an electric needle is applied to the skin, the frog goes through the same series of coördinating movements in the limbs. The result of the motor stimulus is the same in each instance although there is nothing in the frog's experience that would enable it to distinguish between the two stimuli; the nerve cells in the spinal cord receive the acid and electrical stimulus and there results a similar response on the part of the frog. This action is designated as reflex action and yet it looks to our eyes as if the frog were acting intelligently. When the cerebral hemispheres of the frog are removed, the frog swims, breathes, croaks, sees, but lacks the power to initiate movements. This is a further illustration of the way that certain parts of the central nervous system preside over given bodily activities. As one studies the higher animals including man, this differentiation of work is carried much farther until the regions of brain are sharply marked off in the activities over which they preside. The stimulation of one of these definite and circumscribed areas of any one animal always elicits a response in a definite group of muscles and never in any others. Such an area is known as a motor centre. In this way the contractions of the muscles of the arm, hand, and fingers are regulated; the words that we speak, read, or hear are likewise associated with definite regions in the brain.

The ease with which the central nervous system carries on its complicated work depends upon the general state of the whole body. Muscular and mental fatigue, hunger, temperature, and other conditions which affect the condition of the body also have an influence upon the way in which the nervous system works. The effects of opium which usually stimulates the imagination and of alcohol which makes the average person sociable and talkative are easily recognized. Anesthetics are able to cause one to lose consciousness for a time. Disease may weaken the body so as to render one incapable of thinking and when localized in the brain may cause strange defects as the following illustrate: A man, aged forty-two years, complained of an enlargement in the left parietal region; the right side of the body was weakened and there was a tendency to staggering. His memory became poor and when speaking he had definitely in mind what he wanted to say but had difficulty in expressing himself. He gradually grew worse until he could not write at all. A section of bone comprising the outline of the tumor mass was removed by means of trephines and chisels. It was greatly thickened. The dura was found somewhat thickened, but was not opened as the abnormal thickness of bone seemed to be sufficient to account for the symptoms. The man made almost complete recovery, attended to his business as formerly, and seemed well but had some return of symptoms a few months later. Four months later a second operation was performed as the patient was

FIG. 238


A July 16th 1906

Dr. Wm G. Spiller,

Dear Doctor.

We intend to consult Dr. Randall in a few days. I shall, therefore, be obliged, if you will kindly write to the doctor, as you proposed

Very truly,

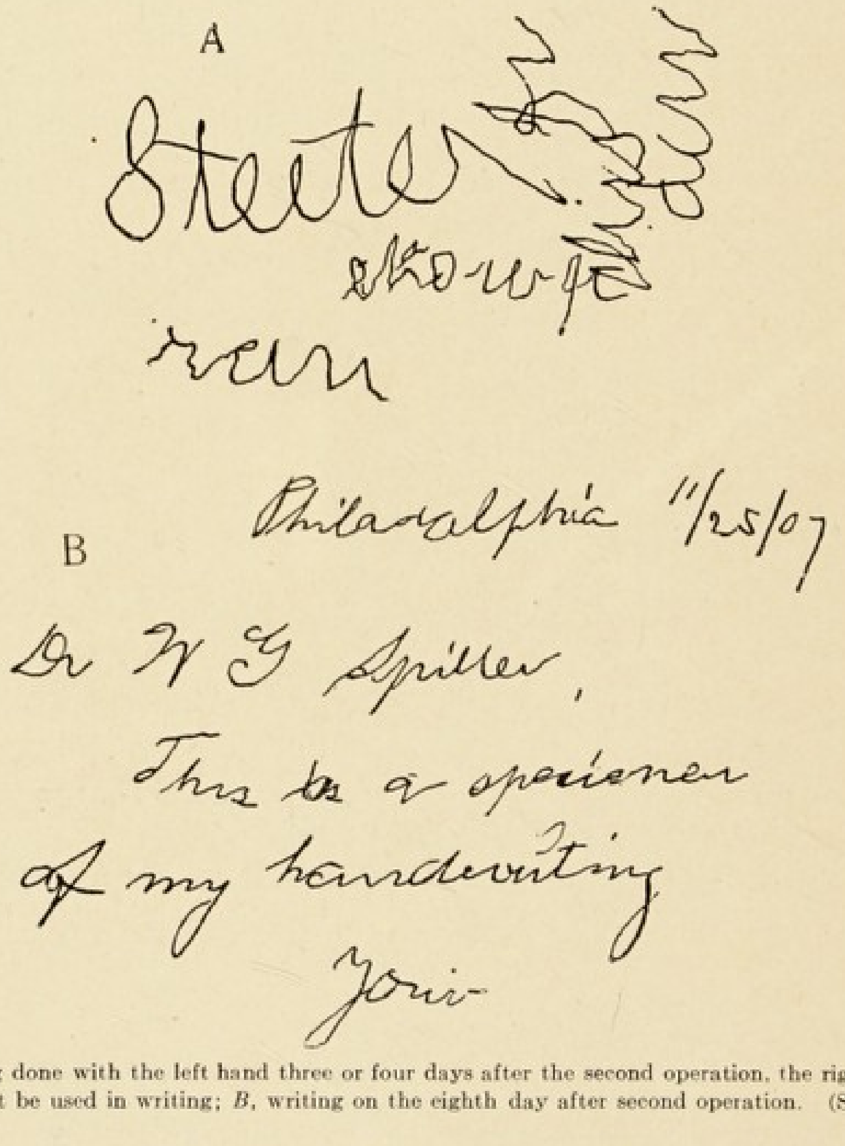
B It is so hard for me to write, that I know you will excuse.

I guess you had better not get ready to come here. I may ago to the Philadely in a wak a week

A, writing nineteen days after the first operation. The man could not write at all for some time before the operation; *B*, writing fourteen days before the second operation. (Spiller.)

unable to write, became confused when he attempted to speak and had difficulty in walking. This time the dura was cut and a tumor was located and removed. Recovery was complete. The most interesting feature of this case is shown in Figs. 238 and 239, which give specimens of the patient's handwriting. The second case is that of a woman, aged thirty-two years, who in childhood had received a blow on the left parietal region from a croquet mallet. The family noticed a gradual development of certain abnormal mental states and sought consultation. When asked if she saw anything unusual, she answered "Yes; holes in the ceiling and walls; small ones; many of them." There was no defect in

Fig. 239



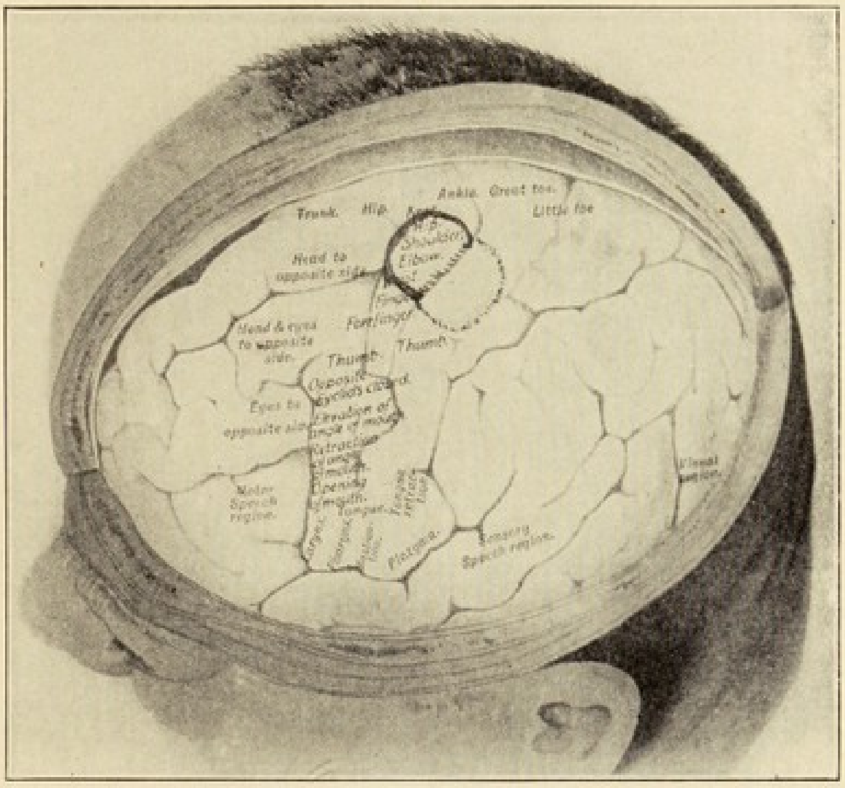
A, writing done with the left hand three or four days after the second operation, the right hand could not be used in writing; *B*, writing on the eighth day after second operation. (Spiller.)

ceiling, nor was it papered. There was nothing to be mistaken for holes; in other words, this was a true hallucination, not an illusion. While the pupillary reactions were being looked for, she volunteered the information that her eyes had been operated upon a short time before and when asked if anything else had been done, she replied, "Yes, my right leg was cut off recently."

A tumor was removed from the hip, shoulder, elbow area of the brain as shown in Fig. 239, and the patient recovered.[1]

The influence of the body on the mind is further shown in the facts of inheritance. As has already been outlined, it is seen that feeble-mindedness and some forms of insanity are inherited. In this connection the normal facts of growth should not be forgotten. For the mental life of the child, the youth, the adult, and the aged are all well-recognized stages and reveal a very intimate relation between the mind and body.

FIG. 240



Location of brain tumor. (Langdon and Kramer.)

Sense Organs.—Animals become aware of their environment and the varied changes in it through their sense organs. In the simple protozoa, the whole external surface acts like a generalized sense organ in being able to receive and conduct such stimuli as fall upon it. It is impossible to state just how many kinds of sensation an

[1] The first case is by Dr. W. G. Spiller, in Amer. Med. Jour., December 21, 1907, xlix, 2059. The second is from Drs. Langdon and Kramer, ibid., December 3, 1910, lv, 1960. Here the full details of each are given.

animal may experience, but it is probable that he has many more than the five kinds usually thought of in the popular mind, *i. e.*, sight, hearing, touch, taste, and smell. "Some kinds of animals have few senses, some have many. Some are strikingly like man in sensibility, others are as strikingly different. The dog, like the

Fig. 241

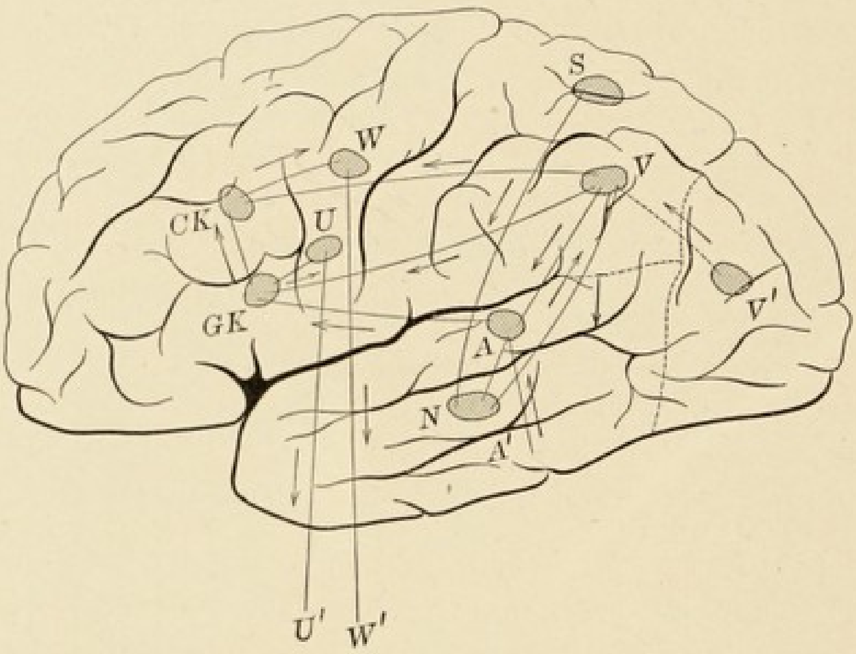


Diagram showing probable pathways of nervous impulses concerned in speech and writing. In right-handed persons these centres and tracts are situated in the left side of the brain; in left-handed persons the opposite is the case. A, centre for auditory word memories in first temporal convolution; V, centre for visual word memories in angular gyrus; GK, glossokinesthetic centre (Bastian), or psychomotor centre, at foot of third convolution; U, centres for muscles involved in articulation at foot of ascending frontal convolution; CK, probable centres for memory of muscular movements involved in writing, cheirokinesthetic centre of Bastian; W, centres for controlling muscles of arm and hand in ascending frontal convolution; A–A', tract from cortex of temporal lobe (auditory centres) to centre for word memories; V–V', tract from cuneus to centre for visual memories; W–W', tract from arm and hand centres to cells in anterior horns of cord and peripheral nerves controlling these muscles (pyramidal tract); U–U', tract from centres for muscles of articulation to centres in pons and medulla and nerves controlling those muscles (pyramidal tract). In speaking, impulses travel from A–GK–U–U'; in reading aloud, from V–A–GK–U–U'; in silent reading, from V–A–GK; in writing spontaneously, V–A–GK–CK–W–W'; in writing from dictation, A–V–GK–CK–W–W'; in copying, V–CK–W–W'; N, naming centre; S, stereognostic centre in parietal lobe. (Potts.)

human being, has a sense of smell, but it is extremely different from the human sense in degree of development. Indeed, so acute is olfactory sensibility in this animal that psychologists have thus far found no way to study it. The dog's sense of sight also is markedly different from man's, for it apparently does not include color vision.

Certain animals, like the lobster and the crab, lack hearing. They are sensitive to slight jars and vibrations in the surface upon which they rest, but they utterly lack what we understand by sensations of sound. On the other hand, there is excellent reason to believe that there are animals in which senses exist of which we have no knowledge. How else are we to explain to ourselves the remarkable ability of certain beings to find their way home or to make long migratory journeys? We must not permit ourselves the thought that all animals experience the same sensations, or even that they possess the same modes of sense." (Yerkes.)

The world that we live in, and the same is true for animals, is determined by the presence of sense organs and the efficiency with which they serve us. One day I read the following to one of our blind students:

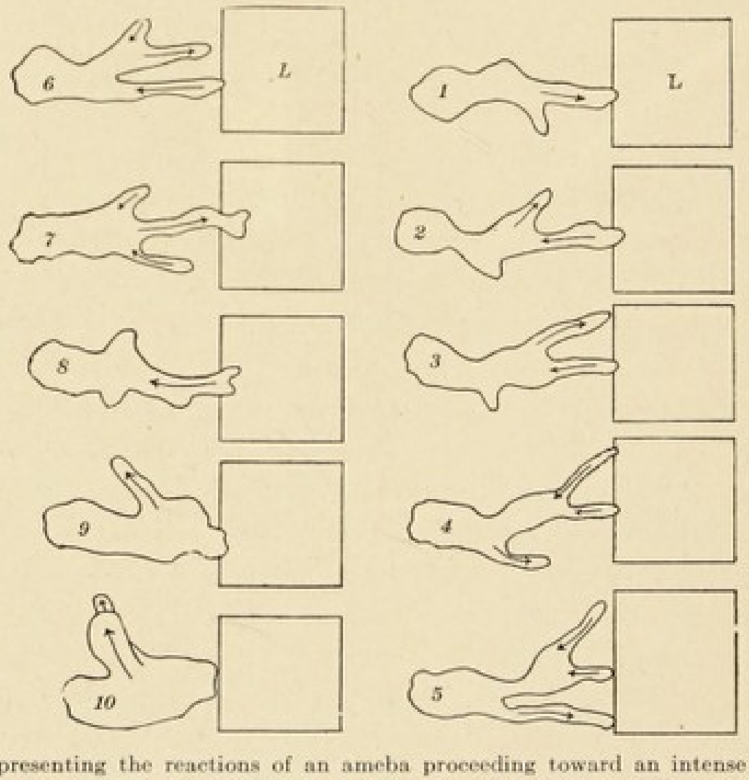
> "His words were shed softer than leaves from the pine,
> And they fell on Sir Launfal as snow on the brine,
> That mingle their softness and quiet in one
> With the shaggy unrest they float down upon."

He was then asked to tell what sort of a picture he had. He could form none because he had never seen the pine leaves falling; similarly, the deaf person lives in a silent world. While the sense organs or their equivalents are the main sources of information concerning the world, yet it is extremely difficult to imagine how the several stimuli in its environment affect the protoplasm of an ameba for example. If it were not for the fact that man can tell us how he feels, thinks, etc., we would have to judge of his mental condition by his actions or, in the case of animals, what we denominate behavior. "Anthropomorphism signifies unjustifiably reading into lower organisms the characteristics, particularly the mental ones, that we find in ourselves, and especially it signifies substituting these for casual explantion. This is a serious error. But it has nothing to do with another question with which it is often confused. This other question is, whether the behavior of animals resembles in any features the behavior of man. This is purely a question of observed fact, not one for prejudice or for *a priori* consideration of any sort. The only way to answer it is to learn the objective facts for man and for animals, and then to compare them, observing where there are resemblances, where differences. Some of these are: the fact that reactions are due to the release of internal energy; that action may occur without specific stimulus; that action is modified by internal changes of the most varied character, many of which are parallel in man and protozoan; that negative reactions are given mainly to injurious agents, positive ones to beneficial agents; that varied reactions occur under the influence of a single constant stimulus, and that the organism tends to persist in that reaction which keeps it in condition favorable to its life processes." (Jennings.)

SOME TYPES OF ANIMAL BEHAVIOR

The following facts illustrate some of the phases of animal behavior. They are such facts as any student can collect himself after becoming trained in making critical observations of this nature. The responses

Fig. 242



Sketches representing the reactions of an ameba proceeding toward an intense area of light the rays of which were perpendicular o the slide. *L*, field of light formed by focussing a limited section of a Welsbach mantle on the slide. 1 to 10, successive positions of an ameba a little less than one-half minute apart. Arrows indicate direction of streaming pseudopods. (From Mast, in *Journal of Experimental Zoölogy*.)

which animals make as thus shown in these quotations are capable of more than one interpretation. The student should consult the texts suggested at the close for assistance in his analysis.

Ameba.—When an ameba is moving about and enters a brightly illuminated area, in nearly all instances it stops. "The details in the response which resulted in the change in direction of motion and thus kept the organism out of the intense light were essentially the same in all of the specimens observed. They are graphically recorded for a single individual in Fig 242. By referring to this figure it will be seen that after one pseudopod came in contact with the illumination and was stopped, the ameba did not at once proceed in the opposite direction so as to avoid the light but sent out other pseudopods at only a slight angle with the first, apparently trying to get around the obstacle in this way. The character of the response did not change after the first pseudopod came in contant with the light, nor did it change after the second and third came in contact with it. But after the fourth became exposed the direction of motion was nearly reversed. This indicates that the reaction was modified, that the response to a given stimulus depends upon preceding experience." (Mast.)

Gonionemus.—This is a medusa with four radigal canals from which gonads are suspended. The tentacles vary in number from 30 to 80. The manubrium is a short stalk hanging from the under surface. "An experimental study of the reactions of Gonionemus to chemical stimuli was begun by observation of the manner in which normal animals react to fish-meat. A small piece of fresh fish placed upon the tentacles causes a reaction which usually presents five fairly well-marked phases: (1) Those tentacles that have been touched by the meat contract, twisting about one another in such fashion as to hold the food and carry it along with them; (2) the group of contracting tentacles bend in toward the mouth; (3) that portion of the margin of the bell bearing the contracting tentacles contracts, thus drawing the tentacles nearer to the manubrium; (4) the manubrium bends over toward the side from which the food is brought, until finally the lips touch the food; and (5) the meat adhering to the lips is slowly surrounded by the manubrium.

"The tentacles of normal Gonionemata react to nearly all stimuli by a contraction which simply shortens the organs, but to some foods and to motile touch stimuli they frequently react by twisting into the form of a corkscrew in contracting. It may now be asked, are these reactions of the tentacles dependent upon the central nervous system? This question finds its answer in the results of experiments upon isolated tentacles. Tentacles were cut from the bell about a millimeter from their attachment and placed in Stenter dishes containing sea water. For a few minutes after excision they usually remained in a contracted condition; then expanded and became very active and sensitive to stimuli. Gelatin or meat applied to them called forth the corkscrew reaction. To other stimuli they respond with the usual straight contraction. It is therefore evident that the tentacle contains within itself the mechanism necessary for these reactions, and is not dependent upon the functional activity of the entire organism, nor upon the central nervous system for its ability to execute them." (Yerkes.)

Earthworms.—Yerkes designed a T-shaped labyrinth of plate glass, with runways 2 centimeters wide, which was used to test the ability of earthworms (*Allolobophora fetida*) to "learn" to follow a simple path and to avoid an injurious chemical (or electrical) stimulus by reacting negatively to a peculiar tactile stimulus which regularly preceded the chemical. He had in mind these two questions: (1) Can the worm profit by experience; (2) can it "associate" the tactual stimulus with the chemical and acquire the habit of regularly responding to the sandpaper as though it anticipated the effect of the salt. From October 12, 1911, to April 30, 1912, a single worm was given 850 trials in passing through the labyrinth under various conditions. The results showed that the worm was capable of acquiring certain modes of reaction which involve a definite direction of movement and the association of two stimuli. He says: "In view of this positive result of training, it was deemed worth while to proceed with the next step in the investigation—namely, amputation of the anterior segments, with the "brain," in order that the relation of the habit to the "brain" might be studied. Forty hours after the operation, it seemed desirable to resume the experimentation. With the apparatus arranged precisely as in the previous series of trials, the worm was permitted to enter the T. It moved forward, more slowly and continuously than before the operation, into the middle of the stem. Having reached the common wall of the arms it turned to the left and five times pushed forward to the sandpaper, each time withdrawing upon contact. As it searched with the cut end, for a way of escape, the "tail" became active and moved about as if "feeling" for a path. Shortly a turn toward the right was made and, with repeated attempts to crawl up the glass wall, the worm approached the exit tube. The instant the "head" end came in contact with the moist lining of the tube the worm pushed forward as in "recognition" of the retreat" (Fig. 243).

"The correct performance of a thoroughly ingrained habitual act of the kind studied in this investigation is not dependent upon the 'brain' (portions of the nervous system carried by the five anterior segments), since the worm reacts appropriately within a few hours after its removal. As the brain regenerates, the worm exhibits increased initiative, its behavior becomes less automatic, more variable. Two months after the removal of the 'brain,' during the last four weeks of which period no training was given, the habit had completely disappeared. Systematic training of two

Fig. 243

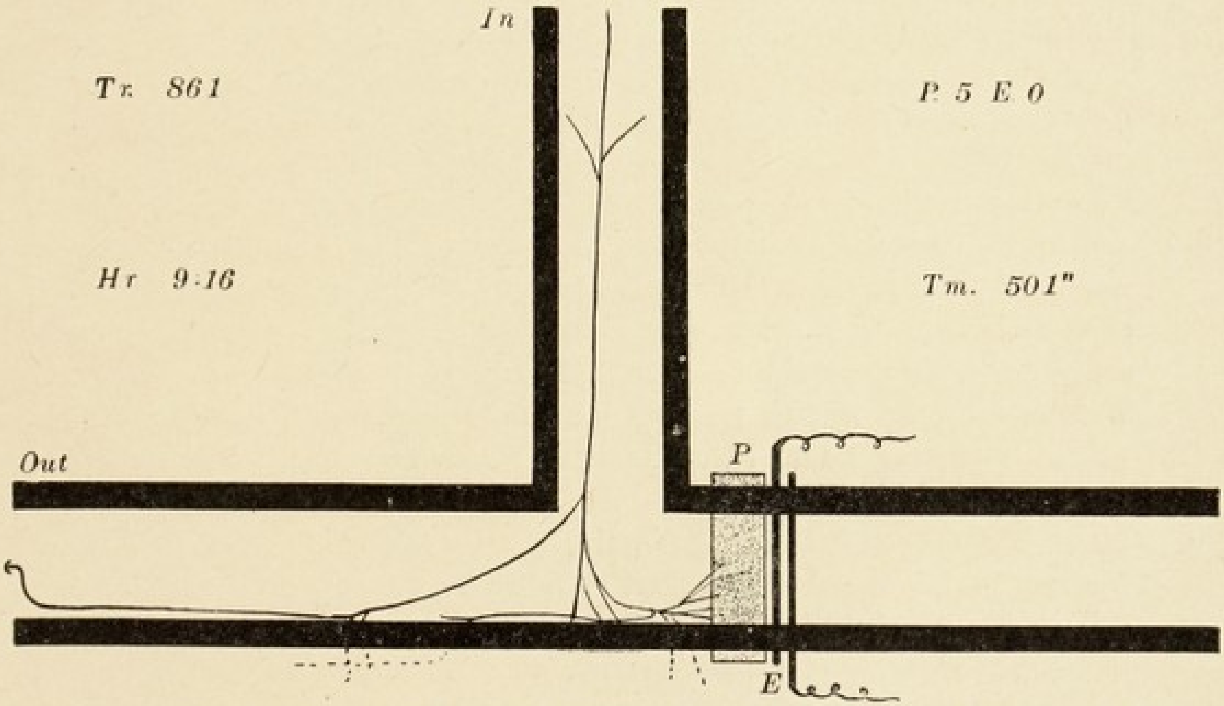


Diagram of T. showing path followed by earthworm in first trial after removal of the brain. *E*, pieces of copper wire serving as electrodes, insulated and kept at a fixed distance from one another by rubber; *P*, strips of sandpaper. (Yerkes.)

weeks resulted in the partial reacquisition of the original direction habit. The various facts recorded in this investigation indicate that the removal and the regeneration of the first five segments resulted in the development of a worm strikingly different in behavior from the original worm." (Yerkes.)

Wasp.—One of the solitary wasps (*Ammophilia*) stores its nests with caterpillars which it paralyzes by stinging the ventral ganglia. "In the three captures that came under our observation, all the caterpillars being of the same species and almost exactly of the same size, three different methods were employed. In the first seven stings were given at the extremities, the middle segments being left untouched, and no malaxation was practised. In the second seven stings again, but given in the anterior and middle segments, followed by slight malaxation. In the third only one sting was given, but the malaxation was prolonged and severe. Of 15 caterpillars some lived only three days, others a little longer, while still others showed signs of life at the end of two weeks. There is not a single species in which the sting is given with invariable accuracy. To judge from results they scarcely sting twice alike, since the victims of the same wasp may be killed at once or live from one day to six weeks, or perhaps ultimately recover." (Peckhams.)

Habit Formation in Frogs.—"July 29, I placed 30 of the hairy caterpillars in the cage. *Rana sylvatica* attempted to eat a caterpillar seven different times within an hour but rejected it each time. Following these trials no other caterpillars were visibly reacted to. By attempting to eat a caterpillar and then rejecting it is meant this: The frog shot out the tongue in the normal manner, bringing the caterpillar back to the mouth, then extruding the tongue slowly, slightly wriggling it. In most cases this muscular wriggling freed the caterpillar from the tongue; if it did not, the withdrawal of the tongue into the mouth scraped off the caterpillar in nearly every case." Omitting some of the details in which this species had similar experience with caterpillars on August 9, 12.30 P.M. "The caterpillar was placed in the cage again, *Rana sylvatica* reacted first by making two short hops to orient so as to look directly at the caterpillar. (The caterpillar was about 5 cm. in front of the frog.) The head of the frog was then slowly lowered and brought forward toward the caterpillar, but I could not see that the tongue was shot out although I watched especially to see if this would happen. In a second or two the head lurched forward a little more and then the tongue was very slowly extended, barely touching the caterpillar. The tongue was now withdrawn and then suddenly extruded, with what appeared as a very slight attempt to shake the caterpillar off. The caterpillar elicited no further response during the next forty-five minutes." (Schaeffer.) For four days the frogs were scantily fed and then a caterpillar was put in the cage. *Rana sylvatica* took no notice of it. *Rana sylvatica* formed the habit of avoiding hairy caterpillars in seven trials.

Raccoons.—"The animals all succeeded in learning to work seven fastenings: namely, two buttons, two bolts, lifted by a pull on each of two loops hung in different parts of a large box, one thumb latch, one bolt raised by the animal's mounting a platform and a horizontal hook placed at the left side of the door. In boxes of two to seven fastenings there is almost no tendency to follow a routine order in undoing them. The average time required for the first success after being put through is very much less than the average time for the first success by trial and error." (Cole.)

Significance of Animal Behavior.—The question naturally arises in what way is animal behavior related to the mind of man. The several illustrations cited in the preceding section indicate that there is no hard and fast way in which an animal reacts to a stimulus, such as a too bright light in the case of the ameba or the manner of undoing the fastenings of a box in the case of the raccoon. It is also very difficult to make a classification such as reflex, instinct, habitual and say that the behavior of the animals already referred to falls into these usual classes. The behavior of animals passes imperceptibly from one stage into another. The number of cases selected has to be limited but when many more are added to the ones given the gradation is more apparent. In short it is difficult to mark limits even to instinct which is usually thought of as acting in an exact and perfect manner. Can one feel sure that the wasp is acting instinctively after reading Peckham's account? The quotations in the preceding section permit one to use Yerkes' very suggestive plan in attempting to explain the history of the development of mind. The rest of this section is taken from his account in his Introduction to Psychology.

The Psychology of One-celled Organisms.—In the opinion of the authorities who have given this matter most careful consideration the mind of the one-celled animals consists of a certain limited number of sense qualities, together with feelings of agreeableness and disagreeableness. The sense qualities are not necessarily the same in all of the animals of the group; on the contrary, there probably are considerable variations. There is no sufficient reason for assuming that the animals experience ideas, memories, emotions, sentiments, thoughts, or any of the psychic complexes which have been observed in man. Their mental lives are extremely, delightfully simple as compared with ours. Theirs must be lives of simple awareness of certain features of their surroundings, without even the consciousness of self as distinguished from environment. There is absolutely no reason for supposing that they are self-conscious. In a word, the organisms of this our first group are psychologically below the level of the infant newly born.

The Psychology of Simple Muticellular Animals.—Here sensations exist in a much greater varity of mode and quality than is the case in the mind of the one-celled animals. Feelings exist, too, and apparently in more complex forms than in simpler organisms. Certain evidences of images, lacking perhaps the elements of recognition or the feeling of familiarity, are discoverable, and we must conclude that the minds of these creatures resemble that of the infant at birth more closely than do those of simpler creatures. Many varieties of worms and crustaceans and celenterates are known to profit by experience in ways which strongly suggest consciousness of the representative sort. But we must not be overgenerous in our ascription of mental states to them.

The Psychology of the Insect Group.—Ants, bees, wasps, and other social insects evidently experience a great variety of sense qualities. There are evidences that their feelings also are vivid and varied. The effective side of their experience consists predominantly of instinct consciousness. This fact, coupled with the observation that a larger number of their environmental relations are definite and almost automatically met in action, has led to the impression that they lack complex experiences and are mere creatures of instinct. It is high time that biology and psychology took account of the fact that instinct as a form of action has as its accompaniment an important effective variety of consciousness.

It is difficult to place the animals of this group in their relation to the history of consciousness in the race. They seem to lie off the direct line of progress and they may well be considered a divergent group. To compare them directly in their mental life with human beings is even more difficult, for in some respects they are more remarkable than the two-year-old child, while in others they are hopelessly inferior. With reason, one might claim that certain of the insects are psychologically superior to man and represent a stage in the evolution of mind which, although strikingly different, is more advanced than our own. And, on the other hand, it must be admitted that the direction in which our mental life has developed is not to be conceived of as a stage in the evolution of insect consciousness. Rather we may conclude that the social insects represent the highest development of mind in one direction; and man, the highest development, in another direction. It is not for us with modesty to insist that our psychic characteristics are best.

The Psychology of the Lower Vertebrate Animals.—The fishes, frogs, salamanders, and toads are far less interesting psychologically than many of the insects. They possess many modes of sense and a fair degree of discriminative ability, but of complex rational experiences, emotions, sentiments, associations, memories, they apparently have few or none. If the mind of man is to be conceived of as having evolved from that of the frog or a fish, a vast gap must be bridged, for there is a world of difference in mental make-up.

The reptiles and birds have a wider range of experiences and, in some instances, they appear to live a life of emotions and memories. Many of them appear to be on the level of the higher insects, although markedly different from them in respect to complexity of instinctive behavior. Rationality of a sort may be attributed to some of them. It is different from ours, doubtless, in that there is less clear and inclusive awareness of the conditions and results of action. Between the most intelligent representatives of this large group of vertebrates and man there is a gap which ages of development might have bridged.

The Psychology of the Higher Vertebrates.—With this group we reach those animals to which we feel mentally most akin. For in the horse, the dog, the raccoon, the squirrel, and others of the mammals we discover experiences like our own. This is not simply because many of these animals are our hearthside companions and patient servants. Even in the creatures of the wild we detect many similar mental traits. For all of the animals of this group, save those toward which we have some special cause for enmity, we have a degree of sympathy and interest which far surpasses that which we feel for the other animals about us. Therefore it is that we object to the abuse or mutilation of a dog, although we may quite calmly eat a live oyster or plunge a living lobster into hot water.

There is no question, in the mind of the person who really knows animals, that the higher vertebrates possess a great variety of sense qualities and feelings. Doubtless these differ in many respects from ours, and even among one another, but on the whole they appear to be more nearly like ours than those in any other group of living things. Of emotions, sentiments, associations, memory images, ideas, and even certain forms of judgment there are more worthy evidences, and the more liberal among psychologists are at present inclined to believe that at least some animals, among them the dog and horse, the raccoon and cat, experience conscious complexes which are much like ours. It is upon this subject that the attention of animal psychologists, who are interested in what animals feel rather than merely in what they do, is now concentrated.

The Psychology of the Primates.—To be sure the primates are higher vertebrates and also mammals, but by their closer resemblance structurally to us as well as by their mental traits, they are entitled to be placed in a separate class. It is not alone in bodily form that they are strikingly like us. They share a large portion of those psychological peculiarities which distinguish us from animals. The monkeys and apes are man-like in their curiosity, their emotional life, their ideas, their memories. Between the other vertebrates and the highest apes there is a great psychological gulf. It is almost as difficult for the imagination to bridge it as it is to imagine the transition from the mental life of the fishes to that of the bird.

For the intimate and thorough student of the animal mind it is by no means difficult to think of the mind of the monkey or the ape as a step in the evolution of the human mind. The difference in mental life is a matter of degree, not of kind. Few traits which man possesses seem wholly lacking in the other primates.

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GLOSSARY

Amanita—A poisonous mushroom, 183
Amitosis—Direct division of the nucleus, 114
Amphiaster—The achromatic spindle present in mitosis, 118
Amphibia—A class of vertebrates, 20
Amœba (Ameba)—A protozoön animal, 96
Anaphase—A stage in the indirect division of the nucleus, 65
Antitoxin—A chemical substance that has power to neutralize toxin, 208
Artery—A bloodvessel that carries blood from the heart, 36
Assimilation—The converting of absorbed foods into protoplasm, 105
Aster—One end of the amphiaster, 67
Auricle—A part of a vertebrate heart usually, but also applied to the invertebrate heart, 36
Axon—The non-branching fiber of a nerve cell, 57

Biogenesis—The theory that life springs from life, 136, 216
Bryophyta—The mosses and liverworts, 156

Carbohydrate—The sugars, starches, etc., 33, 103
Cardiac Valve—Constriction at anterior end of stomach, 24
Cartilage—A form of connective tissue, 45
Cell—A mass of cytoplasm containing a nucleus, 49
Cell Membrane—The outside covering of the cytoplasm, absent in some cells, 51
Centrosome—A small body in the centre of the aster, 67, 118
Chitin—A horn-like material forming a part of the external skeleton of many invertebrates, 150
Chloroplast—The body in the green plant cell which contains chlorophyll, 99
Chromatin—The part of the nucleus that usually takes a deep stain, 67
Chromatophore—Pigment mass, 98
Chromosome—The definite masses of chromatin that form during mitosis, 68, 118
Cilia—Thread-like processes of cytoplasm, see Paramecium, 85
Clitellum—The six to eight somites in the earthworm between the twenty-eighth and thirty-fifth somites, 149
Cloaca—The portion of the digestive canal used in common by the intestine and urinogenital organs, 24
Cnidocil—The hair-like process projecting from the nematocyst, 78
Cœlome—The ventral body cavity of vertebrates, used also for the body cavity of invertebrates, 30
Colony—A group of individuals that are physically united as in hydroids, etc., 86, 141, 178
Conductivity—The power to transmit stimuli, a fundamental property of protoplasm, 52, 111
Contractility—The power to change shape, a fundamental property of protoplasm, 111
Corpora Adiposa—The fat bodies in the frog, 30
Corpuscles—Small cells in the blood, 38
Cytology—The technical study of the minute structure of cells.
Cytoplasm—Cell substance exclusive of the nucleus and cell membrane, 51, 99

Daphnid—A small crustacean, 77
Dendrites—Branching fibers from the nerve cell, 57
Deutoplasm—Stored products in the cytoplasm, 65, 99
Digestion—The chemical and physical changes in the food that prepare it for absorption, 34

Ecology—The relationship of plants and animals to their environment, 154
Ectoderm—The outer layer of cells in the hydra, etc. Also the outer germ layer, 77
Ectosarc—The outer layer of cytoplasm in certain protozoa, 88
Embryo—This name is applied to certain early stages in the development of plants and animals, 70
Embryology—The science that treats of the development of a new individual, 31, 216
Endoderm—The inner layer of cells in hydra, etc. Also the inner germ layer, 77
Endosarc—The internal portion of cytoplasm in certain protozoa, 88
Endospore—The breaking up of the protoplasm into a number of bodies within the cell, 129
Enteron—The digestive canal, 77
Enzyme—A substance produced by living cells which has the power to cause fermentation, 33, 34, 120, 130
Epithelium—One of the classes of tissues, 43
Ergot—A fungus plant, 186
Evolution—The theory which seeks to explain the present conditions of life and its relation to antecedent life subject to the natural laws of the universe, 31, 214

Fat—One of the three classes of foods, 33
Fermentation—The chemical changes which take place in sugars and proteins in digestion, the changes which take place when sweet cider is changed into vinegar, etc., 35, 130
Fertilization—The union or mingling of the male and female chromosomes, 69, 242
Fission—A form of reproduction in simple plants and animals, 91
Fossil—The remains of any part of a plant or animal in the rocks, such as a footprint, a leaf or a tooth, 224

Gametophyte—A plant that produces sex organs, 157
Germ—The ovum or sperm cell. A microscopic plant like bacteria, 61, 248
Glottis—The opening from the mouth into the larynx, 24
Glucose—A form of sugar, 103
Gonium—A colonial protozoan, 141

Habitat—The immediate environment of an animal, 86, 272
Hemoglobin—The red color of the blood, 38, 104
Heredity—The occurrence of ancestral characters in offspring, 224, 240
Hermaphrodite—Having both the male and female organs, 30, 148
Histology—Microscopic study of cells and tissues, 41
Homology—Structures having a similar origin and position on an animal, 221
Hydra—A small fresh-water hydroid, 76
Hyphæ—A portion of the fungus plant, 124
Hypostome—A portion of the hydroid containing the mouth, 76

Immunity—A condition of the body that enables it to resist germ diseases, 205
Infusoria—A class of protozoa, 107
Irritability—The power of responding to a stimulus, a fundamental property of protoplasm, 52, 111

Karyokinesis—Indirect cell division, see Mitosis, 101
Karyosome—A mass of chromatin but not the nucleolus, 50

Larva—An embryonic stage present in the life cycle of most invertebrates.
Life Cycle—All of the stages in the life of an individual, 94–95

Macrogametocyte—A large reproductive cell, 87
Macronucleus—The larger of the protozoön nuclei, 92

Malaria—A protozoön disease in the blood, 190
Marrow—The soft tissues filling the spaces in the bone, 37
Maturation—The formation of the polar cells preparatory to fertilization, 67
Mesentery—A membrane which supports the viscera in a vertebrate, 26
Mesoglea—The non-cellular middle layer in hydroids, 77
Metabolism—The constructive and destructive changes going on in an organism, 40
Metamerism—The division of the body into segments, 147
Metamorphosis—A name given to the life history of insects, frogs, etc., 75
Metaphase—A stage in the indirect division of the nucleus, 68, 118
Metaplasm—A lifeless inclusion in the cytoplasm, 99
Metazoa—The many celled animals, 86
Microgamete—A small reproductive cell, 87, 192
Micron—The unit of microscopic measurement, 127
Micronucleus—The smaller nucleus in a protozoön, 92
Mitosis—The indirect method of cell division, 115
Mycelium—A part of the fungus plant, 124, 186

Nemathelminthes—The class of round worms, 130
Nematocyst—The stinging cell in cœlenterata, 78
Nephridium—An excretory organ, 148
Nerve—A bundle of neurites or axones, 58
Neurite—The non-branching process of the nerve cell, 57
Neuron—The nerve cell with its processes, 56, 57
Neurocœle—The cavity within the central nervous system of vertebrates, 59
Nucleolus—One or more spherical masses of chromatin in the nucleus, 50
Nucleus—A part of the cell, 51, 100
Nymph—A stage in the life cycle of insects.

Operculum—A fold of skin covering the gills, 75
Organism—The living unit, 19
Organs—A part of an animal or plant that has a given work to do, 43
Ovary—The gland that produces egg cells, 28
Oviduct—The duct that carries eggs to the exterior, 28
Ovum—The egg cell, 62, 65, 241

Paleontology—The study of fossil animals and plants, 224
Paramecium—A protozoan, 108
Paraplasm—A lifeless body in the cytoplasm, 99
Parasite—An organism that subsists wholly or in part upon another organism, 165–175
Pentadactyl—Five fingers, 20
Pepsin—The gastric enzyme, 34
Perisarc—The external skeleton on a hydroid. Chapter VIII.
Phagocyte—A white blood corpuscle, 38, 208
Phylum—A class of animals or plants, 136
Physiology—The work that an organism does or the work of its parts, 31
Phytotoxin—Plant poison as in amanita, 130
Pia Mater—One of the membranes that covers the central nervous system, 55
Plasma—The fluid part of the blood, 38
Platyhelminthes—The flat-worms, 138
Pleurococcus—A unicellular plant, 96
Proglottide—One of the segments in a tapeworm, 174
Pronucleus—A germ nucleus. The egg nucleus is the female pronucleus and the sperm nucleus is the male pronucleus, 69, 70
Prophase—A stage in the indirect division of the nucleus, 68
Protoplasm—The living part of the cell divided into cytoplasm and nucleus, 51, 101
Protozoa—The unicellular animals, 86
Pteridophyte—The fern family of plants, 157
Pyloric Valve—A constriction at the posterior end of the stomach, 24
Pyrenoid—Colorless bodies in chloroplasts, 98

Ranidæ—The frog family, 20
Regeneration—The power to regrow lost parts, 83, 149
Respiration—The exchange of gases through a membrane, an essential physiological process in all forms of life, 38
Rhizoid—An elongated cell or cells that acts like a root, 124
Rotifera—A class of worm-like animals, 108

Saccharomycetes—The yeast family, 121
Saphrophyte—Colorless plants that live upon dead bodies, 156
Saprolegnia—A fungus plant, the water mould, 125
Schizomycete—The fission plants, bacteria, 126
Sclerotium—A reproductive structure in the ergot fungus, 187
Secretion—A product of cell activity that serves some useful purpose in the life of an organism, 34
Segmentation—The division of the fertilized egg-cell, 70
Soma—The body cells as distinguished from the germ cells, 244
Somite—One of the segments in the body of the earthworm, 147
Species—A group of individuals that resemble each other more than they resemble any other individuals. The limits of a species are not sharply drawn.
Sperm—The male reproductive cell, 62, 65, 241
Spermary—The organ that grows sperms, 29
Spiracle—An opening in the side of the neck of the frog-tadpole, 75
Spireme—A form which the chromatin takes during mitosis, 117
Spermatophyte—Seed-plants, 159
Spontaneity—The power to initiate a stimulus, believed by many to be a fundamental characteristic of living matter, 111
Sporangiophore—A stalk that bears spores in moulds, 125
Sporangium—A spore-bearing sac, 125
Spores—Reproductive cells that can reproduce without fertilization, 125, 158, 185
Sporophyte—A spore-bearing plant, 157
Sporotrichosis—A disease due to certain fungus plants, 187
Sulcus—A fissure in the spinal cord, 57
Symbiosis—The living together of dissimilar plants or animals or a plant and an animal, 177

Telophase—A stage in the indirect division of the nucleus, 119
Thallophyte—The simplest class of plants, 155
Tissue—A group of similar cells having a similar function, 42
Toxine—A natural product produced by bacteria which has a poisonous effect under certain conditions, 130

Ureter—A duct that connects the kidney with the cloaca in the frog, 28
Urinogenital—The kidneys and their ducts, the ovaries and spermaries, and their ducts, 28

Vaccine—One of the substances used in vaccination, 208
Variation—The small differences that exist between closely related animals and closely related plants, 232
Vein—A bloodvessel that carries blood toward the heart, 36
Ventricle—The chamber in the heart that forces blood into the arteries, 36
Vertebrate—Animal that has a vertebral column, a dorsal nervous system, gill-slits, such as fishes, amphibia, reptilia, birds, and mammals, 140
Vertebral Column—The back-bone of vertebrates, 18, 20, 21
Volvox—A colonial protozoa, 142
Vorticella—A colonial protozoa, 142

Zoöglea—A condition into which bacteria sometimes go as in the "mother of vinegar," 129
Zoötoxia—A toxin produced by an animal, as rattlesnake poison, 130
Zygospore—The spore that is produced when two cells fuse as in vorticella or spirogyra, 98

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