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ELEMENTARY ZOOLOGY

GALLOWAY

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TEXT-BOOK
OF
ELEMENTARY ZOOLOGY

For Secondary Educational Institutions

BY
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WITH 160 ILLUSTRATIONS

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PREFACE.

Teachers of biology are pretty well agreed that the matter and method of our secondary courses in the life sciences should be determined by the needs, capabilities, and life interests of the pupils rather than by any mature conception of what constitutes a "balanced course" in biology. This is to say that the problems of the maker of such a course are pedagogical rather than biological. And yet it is important that the subject should be handled, if possible, in such a way as to give a true and not a distorted conception of biology.

1924 Biol. Dict.
ECONOMIC ZOOLOGY. The most distinctive movement of the last decade, in respect to the teaching of Zoology, is the increased insistence on the practical and utilitarian side of animal life and animal relations in our secondary school courses. It is contended that there is so much of biology directly related to the pupil's life and activities that these aspects of the subject should be emphasized in the peoples' schools, and should replace more and more the evolutionary and scientific conceptions which have dominated the books of the past.

Life
DIVERSITY IN COURSES. As the result of these facts, there are to-day three classes of teachers and courses represented among us: (1) those presenting pure morphological and physiological (evolutionary) zoology, with little reference to the economic aspects; (2) those who make the scientific or evolutionary view primary, and yet supplement this liberally with the economic emphasis; and (3) those who insist that the approach and the emphasis shall be primarily economic,

and that the scientific view-point shall be purely supplementary to this.

The author feels that the drift, whether with sound reason or not, is distinctly toward the third of these attitudes. He has much sympathy for the basal contentions of its advocates. Of all sciences, our own—Biology—should certainly be the first to insist that its content and method should be so ordered as to enable the youth

to secure sound and practical adjustment
 NEED OF to actual life relations and at the same
 GRADUAL time retain adjustability. This seems to be
 CHANGE. the goal of life itself; it should then be the
 goal of biological teaching, since biology is the study of life. We are training men and women, and not zoologists; we are helping candidates for life, not candidates for college entrance. Nevertheless, it is necessary to remember that most of our teachers are trained in the older view; and even if it should be true that the best *ultimate* course in Zoology for high schools will have, as its backbone, the practical, economic, human-interest phase, it is not best that we should too suddenly try to make a break with our whole past. If too wide and sudden a change is made in the whole spirit of our work, we are liable to as chaotic a condition as has held the "nature study" movement in the grades for the last ten years. We need an evolution rather than a revolution in our biological pedagogy.

A COMBINA- This book is an effort to combine the older
 TION OF THE and the newer phases of thought among us,
 EVOLUTION- and is offered as a partial, and yet a dis-
 ARY AND tinct, step toward what the author believes
 ECONOMIC. to be a sound pedagogical and humanistic
 movement. He believes that the secondary

school biology of the future will be primarily concerned about our life interests; but he believes that the great evolutionary conception, which can only be had by some study of the ecology, morphology, and physiology of the animal phyla, is quite as really and profoundly a "human interest" as is stock-breeding, agriculture, or malaria. This conception has changed the whole aspect of human thinking in the last half-century. No course in Zoology which is more than commercial can afford to neglect it.

The present book retains the evolutionary phase as the skeleton of the course. This has largely determined the arrangement of the chapters and of the matter within the chapters. At every legitimate point, however, the author has introduced and placed upon this skeleton material looking toward the economic and humanistic interests of the pupil. Much of this matter is in the form of topics and supplementary exercises for investigation. This form is used because these subjects are intrinsically interesting; they can the more readily be utilized to cause the student to do original work in field or library. They are, therefore, a tremendous strengthening, pedagogically, to any course. The author believes this is much better for the course than to have written out this material as a part of the text.

FOR AN	For any teacher who wishes, and is prepared,
ECONOMIC	to make this economic aspect of the work
COURSE.	the prime part of his course, these supplementary topics and exercises in each chapter

may be assigned first. Afterward whatever is desired of the text, in order to organize this in a satisfactory way, may be assigned. In this event the teacher should secure all possible economic biological literature from the U. S.

Department of Agriculture and the Experiment Stations of the various States. In this way, by varying the emphasis, the book may be used satisfactorily by any of the three types of teachers mentioned above.

EXCESS OF MATERIAL. Because of this effort to meet the demands of teachers of both tendencies, the book is too rich in material and suggestion to allow the members of any class to cover all of it in one year. It is the author's experience, however, that a class does better work when *there is a conscious selection of material out of a larger mass to suit the particular needs of the individual or class*. Furthermore, a *hinterland* of unexplored matter gives a certain sense of incompleteness which should always exist at the end of an elementary course.

Aside from what has been indicated above as to the attitude of the book, the chief contribution which the author hopes, through it, to make to the pedagogy of zoology lies in the following particulars:

SPECIAL PEDAGOGICAL CONTRIBUTION. (1) the giving of *special motives* to the teacher and pupil for each exercise as well as the general motives for the course as a whole; (2) to place emphasis on the *personal processes whereby knowledge is gained* as well as on the matter itself, and upon *completed* processes of knowledge rather than upon partial or aborted ones; and (3) a better adjustment of the arrangement of the material to the natural order of the youth's mental processes.

1. *Motivization*.—The teacher should have in his mind a general purpose to be accomplished for the pupils by the course as a whole, and this should be brought directly to the attention of the pupil occasionally. This, however, is not vivid enough nor near enough to serve adequately either pupil or teacher. The teacher should formulate

for his own guidance, and help the pupil formulate for himself, *some motive—some particular object to be gained by each exercise*. Much of our failure in the sciences, as elsewhere, is due to the lack of this definiteness of purpose. The pupil should be encouraged at all times to raise questions or suggest problems that interest him. This stimulus of natural curiosity will do more to give motive to his work than any other one thing. The “problem-raising attitude” is essential to secure the “problem-solving attitude.” An effort has been made in the table of contents to aid the teacher in formulating special motives for each of the general chapters.

2. *Mental Activity Rather than Information*.—It is essential that we place a larger emphasis on mental attitudes and on habits of intellectual activity, and on the necessary processes whereby sound conclusions are reached, than upon the mere possession of information, whether useful or not. Furthermore, the student is entitled rightly to a *complete mental reaction* when biological or other matter is placed before him. To cause him to observe and record hour after hour without allowing and encouraging the following on through of these observations to conclusions, whether these are correct and final conclusions or not, is taxation without representation in respect to personality. The abortion of the mental reaction and the undue arresting of the normal mental processes always kills interest in youth. The mind must be allowed to come to a natural resting-place, even though it may be necessary to give it material later which will cause it to seek another. It is of course essential that the student be taught to hold his conclusions *subject to revision*, whenever new observations make it necessary.

3. *The Order of the Youth's Mental Activity and Interest.*

—The writer believes that the youth at early high-school age normally gets, and needs to get, a general or synthetic view (howbeit superficial) at the beginning; that this is normally followed by analysis or study of parts; and later again a fuller synthesis of these special studies may be had and is demanded by the mind as a normal completion of its work. This will account for the early presentation of a synthetic view of the animal kingdom (Chapter III) and the general synoptic chapters that introduce the subject broadly, followed by the detailed study of the phyla of animals, and last of all by some chapters giving a renewal and fuller statement of the general or evolutionary view.

The individual chapters are constructed on the same pedagogical assumption.

Certain special devices mark the book in its effort to aid the teacher to keep the problem-raising and solving attitude in the pupil:

1. The brief and superficial keys for the tracing of animals roughly to their phyla or classes or families will be found to meet a need on the part of the pupil. His first question usually is, "What is this animal?" Some most valuable habits of mind are exercised by the use of such keys in the partial self-answering of this question.

2. The suggestions of calendar studies and spring field-work are particularly calculated to bring the pupil into a sympathetic understanding of nature. They further give to the student's interest an *extension in time*, which it is very important that he should cultivate.

3. The suggestive questions in connection with the various figures are designed to increase the student's

appreciation of the figures and to aid him in seeing that for which they are inserted. They should be studied.

4. Whatever emphasis the teacher desires to give to his course, the supplementary topics at the end of the chapters will be found to serve a most useful purpose in allowing the pupil to undertake extra work of his own choosing and in which he himself is interested.

5. Two sizes of type are used. The matter in larger type can be completed by a good class in a year. That in fine print is intended as a background for reference and for extra work. The coarse print outlines a year of work for the teacher who wishes to use the scientific view as primary and to supplement it with a liberal amount of matter involving the human interest.

The author hereby expresses his gratitude to Professor Fred L. Charles, of Illinois University, and to Paul Welch, Assistant in Biology at Millikin University, for assistance and suggestions while the book was in manuscript; to D. Appleton & Co. for the use of figures of the brain; to Dr. J. W. Folsom and to P. Blakiston's Son & Co. for the use of figures from Folsom's "Entomology."

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Time.—3-5 periods.

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ELEMENTARY ZOOLOGY.

CHAPTER I.

ZOOLOGY AND ITS PURPOSE.

1. **Zoology.**—Each of us has some acquaintance with at least some of the many animals that are found on the earth. Some of these are pets with which we are associated daily; some are domestic animals reared and cared for because of their service to man; many more are wild and rarely reach our notice.

In spite, however, of thousands of years of association with animals, we as a race do not know all that is to be found out even of those animals with which we are most familiar, while there are many species of animals man has never studied at all.

The study of *Zoology* includes everything which in any way relates to animals: their form and appearance, their habits of life, their activities and powers, their occurrence on the face of the earth, their relations to other animals, their influence on human welfare.

This knowledge which we actually have, or may get, with respect to animals is said to make a *science* only when it is sifted and verified and arranged in an orderly or systematic way.

2. **The Purposes of Zoological Study.**—There are several practical reasons why Zoology is a good subject of study

for the schools. In the first place, animals are very useful in supplying the necessary conditions for our life. They furnish food, clothing, labor, and protection. The care of animals is one of the most extensive and important of human industries. This may be called the *economic phase* of the subject.

In the second place, many of the diseases which affect man and the domestic animals are produced or introduced by animals. From animals we get many of the medicines with which we fight human disease. Further, man himself is an animal. He is much like other animals in many points of structure and activity. The study of them helps man to see his own place in nature and enables him to meet the various needs of his own life to better advantage. This may be called the *health phase* of the subject.

Thirdly, it furnishes a field of wholesome interest for the human mind, second to none in its inspiration. A person who has studied animals and knows something of their habits and instincts has an increased interest in them whenever he finds them. Any excursion to the woods, or even a stroll along a stream or across fields, has its pleasure multiplied to one who knows something of bees or butterflies or fishes or birds. A knowledge of one or all of these will often take one out into nature, which is always a wholesome and uplifting thing. This is the *cultural phase* of Zoology.

Finally, the study of Zoology, as a laboratory or field subject and not merely through a text-book, furnishes a form of mental training which is valuable for any student, even if he were never called on to use the knowledge. It teaches the student to depend for his conclusions, in large part at least, on his own observa-

tions. It shows him how to observe and how to reach safe conclusions from his observations. It trains in mental accuracy and in self-reliance. This is the *educational phase*.

3. **The Relations of Zoology to the Other Sciences.**—Any department of human knowledge, properly systematized, is spoken of as a *science*. The science most closely related to Zoology is *Botany*, which treats of plants in all their relations. Botany and Zoology, dealing as they do with life and living things, are classed together as *Biology*.

We commonly think of *Chemistry* and *Physics* as dealing chiefly with non-living and inorganic matter, and thus as being in contrast with Biology; but as a matter of fact we cannot understand Biology without taking both Chemistry and Physics into account. The chemical elements, which we find in living matter, are found equally in non-living matter, and so far as we know are subject to the same laws in the living object as on the outside.

Astronomy deals only with non-living things, as the stars and sun and planets; but the astronomical relations of the sun and earth which give rise to day and night, to the seasons, and the like, are of the very greatest importance to all life on the earth.

Similarly *Geology*, which treats of the earth as a unit and of its forces and history, and *Meteorology*, which deals with the atmospheric conditions, are sciences which bear closely on the condition of life, and hence are related in a direct way to the subject of Zoology.

4. **The Divisions of the Subject.**—Zoology, in its broadest sense, includes *all* the facts relating to the life of animals. This embraces man, quite as truly as the lower animals;

and any study of man whether of his physical, mental, social, or moral qualities is a part of Zoology, although we do not usually include such studies in our text-books of Zoology.

For the sake of convenience, names have been given to the various departments or divisions of the study of animals. If we are chiefly interested about the form and structure of animals we call the work *morphology* or *anatomy*; if about the activities and powers of the various parts in relation to each other, we call it *physiology*; if about the way in which the habits or organs of the animal help to adjust it to its external conditions of life and make life satisfactory, we call it *ecology*.

Again, we may study animals with reference to their *distribution* on the face of the earth. We may determine whether they are found on one continent or another; in this or that latitude; whether they live on land or in water, fresh or salt. Evidently many natural forces and conditions enter into such questions as these. (See Chapter XXVIII.)

It is possible to study the life history of an individual animal from its earliest stage to its mature condition, noting all changes in structure and powers and modes of life. This is *embryology*, and is one of the most interesting and instructive fields of Zoology.

If we study animals in respect to their similarities and unlikenesses and classify them into families or groups of more or less similar forms, on the basis of all we know concerning them, we have what is called *systematic Zoology*. By means of this kind of study the animals that have been studied have been named and described and placed in the scheme of classification, as near as possible to the other forms that they most resemble.

Finally, we may study animals primarily from the point of view of their influence on the well-being of man. There is scarcely a human interest to which animals do not in some way contribute. Practically, this is one of the most important departments of Zoology, and will likely receive increasing attention in our schools in the future. This idea of the relation of animals to our human interests should not be absent from the thought of teacher or pupil in any of the exercises. This is known as *economic Zoology*. (See also Chapter XXX.)

5. **The Attitude of the Student Toward the Work.**—In order to get the most out of Zoology, the student must bring to the work a willingness to *use the subject*. The development in the teaching of Zoology has been great in the last forty years; but the student must not be allowed to think that the various devices, as the laboratory, the museum, and the excursion, can take the place of his own interest and effort. Indeed it is even more true of Biology than of most subjects that the best results come to the student from those topics and investigations for which he has sufficient interest and enthusiasm to enable him to forget grades and time and self. Some of the necessary material in a course in Zoology will perhaps seem irksome drudgery to most students; but there is no student who may not find a natural and vital and lasting interest in some of the matter. The student is asked to find these subjects of greatest interest, study them in the library and the field, write themes on them, and organize the rest of the course about them. It does not make any real difference whether the interest is in bees, or in ants, spiders, butterflies, snails, fishes, or birds; it does not matter whether it is in coloration, or in manner of locomotion, or in the mating instincts and care of young, or in the wonderful story of the development of the frog from the tadpole or the fly from the maggot. By all means become interested in something and let the word Zoology always mean to you this one thing as the central thought.

6. **Library Work—a Practical Exercise.**—The student should early learn not to rely too implicitly on his textbook. He has three other sources on which he must learn to make demands: 1, the observations which

he may make for himself in the field and laboratory; 2, statements in other texts which may be available to him as books of reference; and 3, the teacher's fund of information. The latter should be used chiefly to secure a wise use of 1 and 2.

Make, early in the course, a list of all the reference books on Zoology which may be available to you. Each book should be examined with some care. Get an intelligent notion of the kind of contribution it makes to the subject, and make for your own use some notes on the character of the books. For example:

1. Parker and Haswell. Text-book of Zoology, 1897. Two vols. A general text-book, well illustrated; deals largely with structure, and discusses the various animals under their appropriate phyla, beginning with the simplest. Has chapters on distribution, philosophy of Zoology, and history of Zoology at the end of the second volume.

Do not neglect in this exercise the government publications. Many of these deal with the animals that are helpful or hurtful to human welfare.

7. Special Library Topics.—Compare the division of Zoology given in this text with two or three other treatments which you may find in the reference texts. What are the chief points of similarity and of difference between these subdivisions and the one given you above? Make a different subdivision of your own.

In which of these departments of Zoology do you think you will be most interested? Why?

8. Summary.

I. The *natural sciences* embrace:

A. The sciences of inanimate things:
Astronomy,

Geography:

Meteorology, Mineralogy, Lithology, etc.

B. The sciences of animate things = Biology:

Botany,

Zoology:

Of the lower animals,

Of man:

Human physiology and anatomy; Psychology; Sociology; etc.

(Physics and Chemistry are fundamental alike to both groups of sciences; Geology embraces portions of the subject matter of both groups.)

II. The study of Zoology is valuable to mankind because of:

- A. The importance of animals as a support to human life.
- B. The light it throws on man himself and the means of making his life effective.
- C. Increased interest in nature and increased enjoyment through nature.
- D. Cultivation of the power and habit of observation and accurate, independent thinking.

III. The subdivisions of Zoology.

- A. Morphology—the science which relates to form and structure.
- B. Physiology—the science which deals with functions and activities.
- C. Ecology—which deals with the relations of the individual to its whole surroundings.
- D. Embryology—the history of the development of the individual from the egg to the mature form.

- E. Distribution—the occurrence of animals on different parts of the earth and the reasons for it.
- F. Systematic Zoology—which groups or classifies animals according to their likenesses or kinships.
- G. Economic—the branch of Zoology which considers the advantages and disadvantages, both direct and indirect, of animals to man.

9. **Supplementary Exercises.**

- a. Find the root meanings of all the technical words in heavy type or italics.
- b. The following topics will serve for additional theme work in Zoology, and in English.

The chief ways in which animals known to you are helpful to man.

The chief ways in which animals are hurtful to human interests.

What bearing does a study of Zoology have on individual health? on public health?

The satisfaction of knowing something about common wild animals.

What is the most interesting fact of Zoology that you have ever discovered for yourself? Why interesting to you?

How does the power to make accurate observation of facts add to the efficiency of an individual? What part have animals played in the building up of the crust of the earth?

CHAPTER II.

FIELD WORK.

10. **The first need of the student**, in order that the course may be more than a mere book course, is a view of the field and its possibilities. He must actually see and study the country about him, and some of the native animal life as it is found there. Book interest and laboratory interest, while valuable, are both secondary and artificial as compared with this.

The surroundings of our schools are so different that no universal rule can be laid down for the guidance of classes in this sort of work. In general, the large cities are the least favorable place for the study of animals in their natural conditions; but even here the case is by no means hopeless, if the most is made of the opportunities. There are back yards and gardens, vacant lots, parks, botanical and zoological gardens. Oftentimes there are streams or lakes. Each of these has something to contribute which will make the work in class real and natural. Museums have a value in this connection.

In smaller cities and towns, usually a half-hour's walk in any direction will bring the student into contact with animal life varied enough to serve as the foundation of good field work.

The time of the year and the weather conditions cause differences that make specific rules for this work impossible. If, however, the necessity of the field work is recognized, the materials will be found.

11. The Preliminary Survey—a Practical Exercise.—This can be arranged to best advantage by dividing the class into small groups of three or four students. These groups should go out in different directions, the routes being so arranged that all the most fruitful local regions shall be visited by some of the parties.

Every student should observe and make notes of all the types of animal life that he finds, together with a description of the natural conditions under which they are found.

Gardens, orchards, and fields with growing crops should be visited in order to see some of the special animals that are to be found there, and their relation to the plants and fruits.

Similarly, observations should be made and notes be kept of all the species of domestic or semi-domestic animals; also of such animals as can be discovered about house, barn-yards, slaughter-houses, and the like,—as pests.

The purpose of this exercise is to make the class appreciate the possibilities of excursions and to prepare them to take the best advantage of them. For this reason the students should keep in mind the question as to what implements and receptacles they will need when they actually start out on their second and formal *collecting* excursion.

A comparison and full discussion of observations, methods, and conclusions should be had in class.

12. The Collecting Excursion—a Practical Exercise.—Each student should select for careful study one or two of the localities found most fruitful and interesting in the preliminary survey. Let it be understood that the purpose

of this excursion is to find out about the animal life of the locality, and to find subjects and problems interesting enough to be worth the while of the class to study during the year. Every pupil should be encouraged to raise every question that he wishes to raise, and to make whatever suggestions occur to him as to methods of answering his own questions. It is not the purpose of the excursion to allay curiosity, but to multiply it and give it direction.

13. **One of the first practical questions** which confronts the pupil is also one of educational interest: "Where shall we look for animals?" This is a question in animal ecology. Why?

In a general way, to mention the following types of regions will suggest to the student how he must go about his task: among the grasses and low growths of meadows; in hedge-rows and about fences; under logs and stones; in decaying wood; in the trees and on the bark and leaves; about flowers and fruits; among the fallen leaves of forest tracts; in pond and among the sedges and grasses at their edge; in brooks and rivers, shallows and depths; in the soil; in cellars, and other places about our own homes.

14. **Some added matters to be watched for and made note of.**

1. The general character of your territory. What variation is there—of water, land, meadow, marsh, high-land, etc.?

2. In which of these types of surroundings does each of your animal types live? To what extent may it vary its place of life?

3. Anything you discover as to its relations to other animals; or to plants.

4. Its powers, activities, instincts, and habits, so far as they are not outlined above.

5. In what general or special ways does it seem to be well or poorly adapted to its surroundings in structure, in form, size, color, etc.?

Make the excursion a beginning study in the local distribution of animals. What kinds of animals are found in the various kinds of territory? In what various ways are these various forms more suited to this than to some other kind of region? What seem some of the most ready reasons why they are found where they are? Do you think that these early answers fully answer the questions? What is still left to be determined? Have you found any animals that are of any special importance to man? Are all of these *domestic* animals? Are any injurious to man's interests?

The student should keep his mind full of questions like these—not for immediate solution, but as a background for numerous and continued studies. Make a list of all the questions that have arisen in your mind during the excursion. There is no other class of questions so likely to cause you to want to visit the fields again. What do you consider as the most interesting fact or problem that has come to your attention?

15. The Preservation and Identification of Material.—It will soon appear to any student that he must know more about the animals themselves before he can intelligently answer the questions he has asked. It will probably be necessary to use the combined experience of the class, in classifying even approximately the animals found on the trip. The term "worm" or "bug" will probably be made to cover everything except the verte-

brates. Therefore, specimens of the animals discovered should be taken back to the laboratory, in vials or other suitable receptacles, for further study and for identification.

Each specimen taken to the laboratory should be properly numbered, and all necessary notes of the place and circumstances of finding, and of other discovered facts of habit or behavior should be fully kept.

Some of the forms seen cannot well be captured,—as fish and birds and the larger mammals. Notes should be taken of these and an effort be made to adjust them to the general purposes of this preliminary view of the local animal life. A pair of field or opera-glasses will be valuable for the study of such animals.

It is not at all necessary that the student shall know the specific and technical name of every animal found; but one of the very first things needed is the reasonable satisfaction that comes from connecting the various new animals with some type of animal more or less familiar to the student. Or, if this cannot be done, he should know that it is a form strictly new to him.

Each student should thus be brought into personal contact with all the materials captured and with all the data collected by the class, through the effort to trace out the kinship of the forms brought to the laboratory.

If the class has been successful, it will probably have specimens belonging to all of the following groups of animals: earth-worms, and possibly some of the smaller water-worms which may not be seen until the jars of stagnant water have stood in the laboratory for a day or two; snails; mussels; "thousand legs"; "Daddy-long-legs"; spiders; many kinds of insects, as bees, ants, caterpillars, "grubs," butterflies, "bugs," grass-hoppers, and

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the like; "sow-bugs"; crayfish; fishes; tadpoles; toads, frogs, lizards, turtles, and snakes. In addition to these, specimens of birds and mammals will be seen.

In one such outing the members of the class may easily find illustrations of more than one-half of the great branches of the animal kingdom, and gain a general idea of their conditions of life.

[In identifying the specimens the student should use the figures and descriptions in all text-books of Zoology available to him. Chapter III of this book may be studied in this connection, and the "key" on pages 23 and 24 will probably help in the first steps of the classification.]

16. Suggestion to the Teacher.—After the collected materials have been studied and roughly classified, new excursions should be planned to revise, to fix, and to extend the impressions gained from the first collecting trip. These will also be necessary in order to get more materials for the laboratory study. This is the time for division of labor among the pupils, in the collection and field study of particular types of animals. Such work as has now been outlined will serve as the foundation for future individual assignments in ecology and in animal behavior.

Some such study as is suggested in the last sentence should be assigned to each pupil early in the year as "calendar work." Some species of animals (or even a larger group) should be studied during the year, and a report of the observations made to the class near the close of the year. Common species of birds, insects, spiders, fishes, frogs or toads, reptiles, or mammals may profitably be used. First-hand studies of the animal pets or of the other domesticated or semi-domesticated animals are quite as worth while as of the wild forms. Manner of life, individual variation, changes in behavior at different times of year, migration, hibernation, time of reproduction, care of young, and many other similar subjects should be studied.

In this work it is possible to select numerous types of animals that are quite important to man, both directly and indirectly. To mention flies, mosquitoes, cut-worms, clothes-moth, toads, robins, hawks, and rabbits will suggest many others equally as interesting and important.

17. Summary.

1. The introduction to the local field, whether rich or barren, should come early, if we are to get the best results from our zoological work.

2. This introduction can be made appropriately by means of three excursions:

a. A general preliminary survey of the whole field made by the class in sections. No collections; but the students report on the conditions, and plan a collecting excursion on the basis of the information gained.

b. One or more general collecting and note-taking excursions to chosen types of localities for the purpose of getting all possible kinds of animal life. Everything should be labeled in such a way that all the facts about any specimen may be available to every student.

c. Special limited excursions by small parties or by individuals, for more exact study or for special specimens and as basis for written reports to the class. These should be continued until the teacher is satisfied that all the members of the class really *know* something, at first hand, of the life of the locality for a radius of a mile or more from the school.

3. Every pupil should determine to which of the great divisions (*phyla*) of the animal kingdom each specimen brought to the laboratory belongs. Whenever possible the identification should proceed to the point of locating the animals in the principal subdivision (*classes*) of the main branches (or *phyla*).

18. Supplementary topics for themes in Zoology and English.

1. The differences between the animal life of forests and meadows.

2. The differences between pond life and brook life.
3. Do you find any water forms that seem at home on the land? That do not? Any land forms that seem comfortable in the water?
4. Do you find any water-loving forms that seem similar to animals that prefer the land?
5. In what general respects does the animal life of autumn differ from that of spring and early summer?
6. What types of animals do you find adopting a distinct boring or burrowing habit? Into what kinds of materials do you find them burrowing? What seems to be the purpose of this mode of life, in the various cases?
7. Have you been able to discover any clear case of *mutual* adjustment in the habits of any two species of wild animals?
8. Any such interrelation between any type of animals and any species of plants?
9. To what extent do any of the kinds of animals that you have found appear social? Just what do you mean by "social," in this answer?
10. To what extent do the various animals seem active? Do their activities seem aimless? Justify your conclusion. Are the activities constant?
11. What group of animals do you find represented in the greatest numbers in your collecting and observations? What do you take this to mean?
12. Among the wild animals you have actually seen, how many are known to you to be important to human interests? Which are helpful? Which hurtful? Which of these affect man *directly*? Which indirectly?
13. Classify all the domestic animals that you know. Write them in smaller groups according to their like-

nesses and differences. What are the chief reasons for the value of each?

14. How many household animal pests can you mention? To what animal groups do they belong?

15. How many garden pests? What is the nature of their work?

16. What orchard pests are you familiar with? Give a brief account of their habits.

17. Find by examination, by conference with farmers, by reference to the library, what animals are most injurious to corn in the various stages of its growth. Similarly, to wheat; to the elm, to the currant, etc.

18. Can you think of any animals that would fall in a class of "semi-domesticated" animals. Enumerate and discuss.

CHAPTER III.

CLASSIFICATION OF ANIMALS: GENERAL SURVEY.

19. Before undertaking any special work on any of the branches of animals, the student should get a general glance at the whole field of animal life, which will enable him to use to best advantage the facts that he has already discovered, more or less incidentally, during his life. The diagram, Fig. 1, will aid in bringing the animal kingdom in review. This chapter should be studied in connection with the animals actually brought in by the students in the collections described in the preceding chapter.

20. **Mammals.**—Man is the highest animal. Similar to him in many ways are the apes and monkeys. More unlike him, and yet similar in numerous remarkable particulars, are the horse, the ox, the dog, the cat, bears, squirrels, bats, whales, and seals. All of these bring forth their young alive, after the embryo has been carried for a considerable time and brought to a reasonable maturity in a special organ in the body of the mother. After birth, the mother nourishes the young by means of milk, a special secretion of the mammary glands. This is seen in no other group beside the mammals. The skin produces hair or wool, as a partial covering for the body. Man differs somewhat from the other mammals in his structure, but not nearly so much as he and the other mammals differ from all the other animals.

21. **Birds.**—Another well-developed and numerous group of animals is the class known as birds. There is scarcely another class of animals so easy to distinguish, at sight, as this. They equal or surpass the mammals in specialization, but are very different from them. They are to be recognized by the body covering of feathers, instead of hair; by the modification of the front limbs into wings for the purpose of flying; by their large, shell-covered eggs; and by the fact that the jaw has a casing of horny matter and does not, at least in the case of modern birds, bear teeth.

22. **Reptiles.**—This class is not nearly so easy to recognize or to define as either of the preceding. This is partly because the animals

FIG. 1.—Diagram showing the general relations of the chief divisions of the animal kingdom. The number of species (the numerals) belonging to each division is only roughly approximate.

in the class differ more among themselves than those in the other classes. It includes snakes, lizards, turtles, and crocodiles. Their bodies are covered by scales or plates, instead of hair or feathers. They lay large eggs very much like those of birds. They always breathe oxygen from the air, like birds and mammals, even though they may live in water. The blood is not constantly warm as in the birds and mammals.

23. **Amphibians.**—In outward appearance some of the members of this class look like some of the reptiles. Like the reptiles they are cold-blooded. They do not have the scales and plates in the skin, but are of smooth and even slimy surface. They are especially noteworthy from the fact that they begin life breathing oxygen from the water by gills, as fishes do, and later in life lose their gills, acquire lungs, and get their oxygen from the air, as do the higher forms. Amphibians include the frogs, toads, and salamanders. This is not a very important group in nature, but it is intensely interesting to the student of zoology because it seems to be a connecting link between the water-breathing and the air-breathing animals.

24. **Fishes.**—Fishes are characterized by the fact that they breathe by means of gills throughout life. The body is often scaly; the appendages are fin-like, instead of jointed legs; the blood is cold and the heart has only two chambers. They are beautifully adapted to life in the water and are easily recognized, as a rule.

25. **Vertebrates and Invertebrates.**—All the animals of which we have thus far spoken agree in certain particulars. They all have a dorsal rod of cells—a kind of internal supporting skeleton—which, in its most developed form, we call the *vertebral column* or “backbone.” The nervous system is always dorsal to this rod. The heart is ventral to the digestive tract and the blood has red corpuscles. There are never more than two pairs of jointed appendages (legs, arms, wings, etc.). They are all known as *Vertebrates*. All other animals, except a few which seem intermediate in some respects, are classed as *Invertebrates*, and agree in the following particulars: there is no vertebral column; the nervous system is chiefly ventral to the digestive tract; the heart, when present, is dorsal; and the blood usually has only colorless cells; there is no definite number, or arrangement, of appendages. The principal divisions (*phyla*) of the invertebrates follow.

26. **Arthropods.**—This phylum embraces more kinds of animals than all the rest of the animal kingdom put together. It includes

(1) crayfish, lobsters, crabs (*Crustacea*), which for the most part have gills and live in water; (2) the *Insects*—as bees, flies, beetles, butterflies, etc., which usually live in the air and get their oxygen from it; (3) the *Spiders*, whose habits and appearance are somewhat similar to those of the insects. The arthropods are to be recognized by the fact that their bodies are made up of segments, are bilaterally symmetrical (that is, have a right and a left side), and have paired jointed appendages to many of the segments. In addition to this, there is an outer protective covering (skeleton) developed by the skin. This is resistant and serves for the attachment of the muscles which lie within it.

27. **Mollusks.**—This phylum of the invertebrates includes the snail, the clam and oyster, the squid and devil-fish, and their kind. They differ very much among themselves, but they agree in the lack of segmentation of the body, in the absence of paired appendages, and—in those types most commonly known to the student—in the presence of a protective limy shell, of one or two “valves,” which is secreted by a fold of the skin known as the *mantle*. Most of the mollusks are lowly in organization and in intelligence; the squid, however, has the most highly developed brain found below the vertebrates. It occupies among the invertebrates somewhat the place which man has among the vertebrates.

28. **Echinoderms.**—These are easily recognized in the adult stage by the five or more arms or rays that radiate from the central point. Because of this arrangement they are described as radially symmetrical. Usually a skeleton, bearing spines, is developed in the skin. They are found only in the sea and are poor movers—some of them being actually attached to the bottom by stalks. The starfish, sea-urchin, and sea-lilies are representatives.

29. **Annulata (Segmented Worms).**—The earthworm is the best known representative of this group. Annulata are similar to the arthropods in several particulars. They are bilaterally symmetrical, the body is segmented and has paired appendages on many of the segments. The appendages, however, are not jointed, but are merely *setæ* or hairs, in sockets or on fleshy prominences. The segments are more nearly alike in the different parts of the body than they are in the typical arthropods. The larval stage of insects (caterpillars, grubs, maggots, etc.) are likely to be confused with the segmented worms, if the student is not watchful. Besides the earthworm, the leeches and many aquatic worms, both fresh water and marine, are included here.

30. **Unsegmented Worms.**—Under this name we may include a number of small—often microscopic—animals which do not belong to any of the well-recognized phyla of animals. They are bilaterally symmetrical, for the most part; they are not segmented, and do not have the paired appendages. Many of them are parasitic; but others live in stagnant waters, and some of these are likely to be found at almost any time in preparations standing in the laboratory. Here may be included the “tape-worms” and other “flat-worms”; trichina and other “thread-worms”; “wheel-worms,” etc.

31. **Cœlenterates.**—This group is wholly aquatic and chiefly marine. It includes the jelly-fishes, sea-anemones, corals, and other polyps. They are more or less tubular, sac-shaped animals, often attached by one end. The mouth, which is at the free end, is surrounded by a cluster of tentacles. The digestive tract has no other opening than the mouth. Many of these animals secrete limy skeletons, and some form immense attached colonies by their power of budding—the young individuals retaining their connection with the parent stock, somewhat as the new branches of a tree are related to the old ones. The internal structure of the cœlenterates is not so complex as that of the groups mentioned above.

32. **Porifera.**—This group, which includes the sponges, is sometimes classed with the cœlenterates. While similar to them in general habit, the sponges are much less highly organized and unified. Instead of a single mouth, opening into the digestive tract, the sponges have many openings or pores (whence the name *Porifera*) which are the beginning of tubes carrying the currents of water to a central cavity. This cavity communicates with the exterior by means of one or more large outlets. The sponges are mostly marine, are attached, and form large colonies by budding and remaining together, as do the corals. The ordinary sponge of commerce is the skeleton of such a sponge, after the fleshy or living part has been removed.

33. **Protozoa.**—All the preceding phyla of animals consist, in the adult stage, of individuals made up of many cells among which there is more or less differentiation into tissues of several kinds. In all of them the individual passes, in becoming adult, through stages in which the cells are arranged in two layers (ectoderm and entoderm; see p. 121), and from these layers all the tissue masses arise. All such animals are known as *Metazoa*. In the remaining phylum—the *Protozoa*—the adult is a single cell, or at most a loose and poorly

organized body of similar cells. They are the lowest of animals, are found only in water and moist places, and are usually invisible to the unaided eye.

34. Key for the rough identification of the animals the student is most likely to find.

A. Microscopic, or at least minute; chiefly aquatic.

I. Unicellular, or if of several cells these are loosely associated *Protozoa*.

II. Multicellular, with definite organs; the individual cells not easily distinguished

1. Body not composed of a series of segments, moves with a gliding motion by means of cilia.

"Flat-worms."

2. Body showing evidences of being made up of segments. Segments obscure; a disc of cilia about the mouth, giving the appearance of a rotating wheel.

Rotifers (Wheel-worms).

Segments manifest: two or more clusters of hair-like appendages on each segment. *Annulata* (aquatic).

Segments variable: numerous paired appendages jointed *Crustacea* (Water-fleas).

B. Not microscopic.

I. *Purely aquatic; chiefly marine.*

Not symmetrical, growing massive, attached. . . *Sponges*.

Radially symmetrical—the repeated structures arranged radially.

Attached and often colonial . . . *Cælayerates* (*Polyps*).

Free-swimming; jelly-like . . . *Cælayerates* (*Jelly-fish*).

Free, but sluggish; skeleton and spines (commonly).

Echinoderms.

II. *Marine, fresh water, and terrestrial.*

Without conspicuous paired appendages (including fins, legs, wings, etc.).

With protecting shells *Mollusks* (See p. 227).

One valve or piece; usually spiral.

Snails, Periwinkles, etc.

Two valves to the shell. . . Clams, Mussels, Oysters.

Without protecting shells . . . *Worms*. (See p. 204.)

(Here might be found also some insect larvæ).

Not strictly aquatic, but in moist places.

Annulata (Earthworms).

CHAPTER IV.

LABORATORY WORK: FORMS OF MATTER.

36. **The Spirit of the Laboratory.**—The student cannot gain the best results from his course in Zoology without appreciating the part that the laboratory may have in the work. The chief purposes of the laboratory are as follows:

1. To serve as a foundation and illustration of the work of the text-book and the lecture-room. Any description is always more full of meaning if the student has something in his own observation and experience with which to associate it.

2. As related to the field work, the laboratory is intended to bring the student into a closer relation with the objects studied. The materials are in more natural condition in the field, but they are less under the control of the observer. The laboratory work is of a more intimate type. The student can also control the conditions of all his experiments better in the laboratory. The field and the laboratory must be looked upon as supplementing each other.

3. The laboratory should also be used by the pupil and by the teacher to test and *consciously* to develop the mental processes of the student. The purpose of the laboratory is to produce *effective* students, and for this reason the student should not only become interested in animals and their structure, powers, and reactions,

but should have some knowledge of the mental steps he himself is taking in the various exercises, and should learn to enlarge his own ability to take the steps necessary to reach accurate conclusions. The schools have no place in which this may be done to better advantage than in a properly conducted biological laboratory.

A Laboratory Exercise. Forms of Matter.

37. **Observation.**—Take a series of objects, such as fine sand, pebbles, crystals of several kinds, shells of several kinds, plants, and animals. Examine each of these objects carefully, and write down in an orderly way *every observed characteristic* which you can discover. See that no complex idea, which is reasoned out, is used. Take nothing from books; just record your individual observations. For example, you may want to say that sand is not living or that animals are living. Are these *real observations*? Can you observe life?

a. *Sand.*—Use some fine mixed sand. Examine it under the microscope, as well as with the natural eye. After studying numerous grains, enumerate the various qualities that are true of the grains *collectively*. Put only *one* characteristic in each statement, and be sure that your language expresses exactly what you want to say.

Can you observe the sand itself? Or do you merely observe qualities of the sand? Reasons for your answer?

How do you observe? In how many different ways? By what means have you actually observed *each* of the qualities you have enumerated?

Compare the various qualities of sand which you have mentioned. Are they all of equal importance? Which

of the qualities, that you have written, are *essential*? That is to say, which of them are necessary to make it sand? If a visitor were to come into the room, and your list of characteristics were read, would he be able to know that you were studying sand? Why? If not, what qualities would you need to add? Why have you written these qualities in the order you have chosen? Do you believe yours is the best order? Why? Are some of the observed characteristics related to others? Can you group your qualities in such a way as to bring together those that are more related? What do you understand by "related" in this connection?

If you were to rearrange your list, on such a basis as this, in what respect would it differ from your present list? Would it be a more satisfactory arrangement?

How many of your qualities would come under the head of "form"? How many under the head of "composition"? of "optical qualities"? What other heads would be needed in order to include all the other characteristics you have mentioned?

b. *Pebbles*.—Rough and smooth and of various sizes.

Treat these just as you did the sand, but do not allow any *comparison* to come into your statements. In other words, study and write of the pebbles as though you had not studied the sand.

c. *Crystals*.—Study these as above, answering similar questions concerning them. Use as many types of crystals as you can get: quartz, gypsum, iron, lead, etc. Many types of crystals may be made economically by making a saturated solution of certain salts in hot water and allowing the water to cool; or place a small portion of the solution on a glass slide or in a watch-glass and allow the water to evaporate. The following substances

will make satisfactory crystals if treated in this way: common salt, alum, sodium carbonate, blue vitriol. Examine the smaller crystals with a lens or microscope. Draw a few of the simpler crystal forms.

Enumerate your observed characteristics in such a way that your statements will be true of all your crystals and not merely of some selected crystal. Does your list describe the crystals in such a way that a newcomer would understand from it alone what you have been studying?

Of the characters mentioned, which seem to you most distinctive; that is, which seem to make the crystal a crystal? If you were to break a crystal would you have a number of small crystals? Why? How would you name the quality which makes this true?

d. *Shells*.—Use as many different kinds of shells as you can get conveniently. Study as above. What qualities are common to all the shells? Draw one or two figures of shells. Which characteristics make them shells? Which are incidental qualities; that is, so variable as not to affect the “shell-ness” of the shells?

Do not mix observations and inferences.

e. *Plants*.—Note the characteristics of plants in the same way.

In this exercise it is legitimate to use all kinds of plants that you are familiar with, whether you actually have the specimens in the laboratory or not: as trees, shrubs, herbs.

The teacher should also supply some specimens of mosses, of mushrooms and toadstools (*fungi*), and some of the green felt-like plants (*algæ*) that grow in water.

Is there anything you can actually *observe* that is common to all of these? You cannot directly observe

that it is alive or not alive; hence this should not be a part of your record of observations. This is an inference based on certain observations. What? How many distinct statements of observations can you make that are true of *all* these plants? Which seem to you essential to their *plant-ness*? Why? If you cut a plant in two, do you have two plants? Can you give a name to the quality of plants that makes this true?

f. *Animals*.—Study animals as you have the plants, using all the animals you have actually seen in your study. Do not introduce into your lists any comparisons of animals with plants or with other objects that you have been studying. Write as though you had only studied animals, and use only simple, observable qualities. Which seem to you the most distinctive characters? which of your list do you think of particularly when the word “animal” is used?

38. **Discrimination**.—Go over your lists again now and compare carefully the various qualities of sand. Are they all equally important and full of meaning in making it sand? Why are some characteristics not as significant as others? Check the essential characteristics in some way. Treat each of the other lists similarly.

39. **Comparison of Objects on the Basis of their Observed Qualities**.—If, now, we undertake to compare the various classes of objects with one another, as sand with pebbles or shells, which will be more useful in the comparison—the qualities you checked (38) or those that were not checked? Why?

What are the important distinctions between sand and pebbles? What qualities distinguish crystals from the sand and pebbles? Can you find a suitable name

for the condition in the crystal which make it impossible to break it into several complete crystals? Was this true of the sand grain or the pebble. Does this strike you as important? Why? Is this quality found in shells, and plants, and animals?

What qualities seem to you to distinguish the shells from the crystals, pebbles, and sand? Are the different regions of the shell more different from each other than are the parts of the preceding objects? Justify your answer. Find two or three terms that express this idea. Which is the best term? Why? Do plants and animals show this new quality which you have just named?

In a similar way compare the plants and animals you have observed with the forms that have gone before and with one another, and note the points of similarity and of contrast.

40. Classification of objects on the basis of observed qualities.

a	b	c	d	e	
				{	Sand 1
				{	Pebbles 2
				{	Crystals 3
				{	Shells 4
				{	Plants 5
{	{	{	{	{	Animals 6

If you were asked to break up these six classes of objects into two groups, which of the divisions indicated above by the sets of brackets would you prefer? That is,

which seems to you most natural, and most in accord with your observations concerning them. What characteristic are you using as the basis of the division you have chosen? Should a first division, such as this, use the *more* fundamental or the *less* fundamental characteristics? Why?

Can you select qualities from your list that would allow you to use in turn each of the other methods of division indicated by the brackets. (Note that *any* classification involves both likenesses and differences; for example, brackets "a" means that 1, 2, 3, 4, and 5 have some qualities or absence of quality in common, and are in this respect different from 6.)

What characteristics, that you have discovered, should be written after the numerals in the following skeleton classification, in order to express the steps?

Illustrate as many other ways of grouping these six types of objects as you can. Notice how the basis of classification (*i. e.*, the quality that you choose to use *first*) *determines your classification*. In the above diagram read successively the characteristics (the 2's) leading to animals, and see if such a classification implies at least a partial definition of the objects classified.

41. Generalizations, or Statements of General Truths or Principles.—Do the following general statements seem proper inferences to draw from your studies?

1. Objects, *i. e.*, “forms of matter,” are found in nature, in at least four types: (a) *amorphous*, without definite or predicable form; (b) *crystalline*, regularly bounded by plane surfaces and straight lines, coming together at more or less definite angles; (c) *non-living products of life*; and (d) *living objects*.

2. Living objects and the organic products of life have a degree of differentiation into regions or parts which is not possessed by the other classes.

3. Some classes of objects seem to take their particular form as the result of external activities (pebbles); others appear to have some inward control over the shape which the whole assumes (crystals, plants, etc.).

4. Non-living matter, brought together by the life processes (shells), seems to have some of the complexity of form which characterizes living objects themselves.

5. There are two classes of organized matter—shells and organisms.

Make other similar generalizations, being careful to base them on your former work.

42. Testing Former Generalizations by Renewed Observations.—Is a study of six classes of objects, in the way in which we have been studying them, sufficient to enable us to make a *complete* statement of the differences between organic and inorganic objects? or between living and non-living? Why?

Could you substitute four classes of objects for the sand, pebbles, crystals, and shells that could have been used in our exercise to illustrate the same general truths

and classes of matter similar to those which have been mentioned?

Where, in such a scheme as we have worked out, would grains of starch fall? Where a feather or a tooth? Where would a watch or a microscope belong? Where a dead bird or a dead tree?

Is a planet or a drop of oil a "form of matter"? Is either of these amorphous, or crystalline, or organic (not living), or organic (living)? What then?

Are the words *organic* and *living* synonymous? In what way are they related?

43. Some Definitions and Questions.—What are the differences between the *unity*, or degree of *individuality*, of the sand-grain, the pebble, the crystal, the shell, the plant, and the animal?

Just what would be meant in any of these by *organization or differentiation of parts*? Which is the first of our series of objects to show this quality in marked degree?

To what *purpose* does such differentiation in the shell seem to point? What is the effect of it on the *degree of individuality* possessed by an object?

Do activities and powers, or the structures, seem to you more usable in furnishing the distinctions you have been making between plants and animals and between them and the other objects?

Define: organic, inorganic, organism, living, individual, differentiation of parts, quality, amorphous, crystalline, in terms of the practical work you have been doing. Are they needful terms? Compare your definitions with the definitions of the books.

44. The Order of the Mental Processes in the Laboratory Exercises.
—a. *Observation.*—What do you understand by observation? What of your own powers have you used in observing? Test the various

qualities you have written of the objects and determine by means of what sense you discovered each? Are any of the observations obtained by the combined work of two or more senses? What sense do you use to determine that the pebble has weight? Just how do you observe "roughness"? In what way do we get our idea of the form of objects? How many elements are included under "form"?

Just what do you observe? the object itself or the qualities and properties of the object?

Do people differ in their powers of observation chiefly because of difference in clearness of vision, sensitiveness of touch, and sharpness of taste? What then? What is the difference in your individual mental attitude when you are observing carefully and accurately, and when you are not?

(Be sure that your observations are properly recorded; that your notes really say what you want them to say and only that. Accurate statement is almost as essential as accurate observation.)

b. *Comparison of the Qualities of an Object.*—Are certain of these enumerated qualities more closely connected with each other? Are color and translucency more nearly related than either is to shape? Compare *all* the statements you make of one class of objects, and bring together under proper headings those that fall more naturally together, as form, size, outline, etc.; structure, composition, etc.; activities, powers, etc.; and so on through the list.

Just how does your mind work while comparing? What is the value in being able to do this?

c. *Discrimination of Qualities.*—Are all the qualities which you observe of an object equally important and fundamental to the object? Is the ease or difficulty of observing a quality the thing that determines whether it is important or not? How, then, can we tell when a quality is an important one?

One of the most important powers for the pupil to acquire, either for successful laboratory work or for life, is the power to distinguish between *essential* things and *incidental* things; and yet the student must be cautioned against being too sure that a quality is unessential. Features of seemingly slight value often prove important.

One of the greatest advantages of laboratory work in the biological sciences is the cultivation of this power of discrimination.

d. *Comparison of Objects on the Basis of Their Important Characteristics.*—What is the value of this? Can we compare *objects* directly? How did you compare sand and pebbles?

Comparison brings out two classes of relations: agreements and disagreements. Both are important.

e. *Classification of Objects*.—In classifying we place objects together in groups in accordance with their essential similarities and dissimilarities. The value of a given classification depends on the basis used and on the accuracy with which the preceding steps have been taken.

The value of the power of accurate classification is considerable. Classifying furnishes one of the first resting places for the mind in its investigations. We are not satisfied, on observing a new phenomenon, until we are able to classify it with or near to some other, already known to us.

Classify the pupils in the class, or the books in the library. How many and what *bases* can you use? What different results do you get?

f. *Inferences, or the Deduction of Rules or Principles*.—A scientific classification is one mode of expressing certain truths. These truths, however, may be put into definite statements. The power to make correct inferences from known facts is one of the most important which a student can acquire.

g. When a student has taken all these steps and has reached the conclusions that seem most probable in the light of all the facts he has, he should still hold this conclusion as subject to possible modification by the discovery of new facts. This attitude of mind we call the "scientific spirit," and the method of work outlined in this chapter is called the "scientific method." One of the chief purposes of the study of the sciences is to give the pupil this spirit and method.

It is not necessary for the student to stop and take these various steps *consciously* in every investigation; but he should recognize that these are the normal steps to truth, and be able to know which he is taking at any moment.

45. **Practical Exercise**.—Suppose you were proposing to select a limited number of friends out of one hundred new students. In order to do this wisely and satisfactorily to yourself, would any of the processes described in this chapter be necessary? Illustrate fully.

CHAPTER V.

LIVING AND NON-LIVING OBJECTS.

46. Similarities Between Living and Non-living Matter.

—In matter that is alive we find numerous chemical elements, as carbon, oxygen, hydrogen, nitrogen, sulphur; also, in less degree, potassium, sodium, iron, phosphorus, and others. These elements are found also in non-living states, both alone and in compounds. Similarly we find water and carbon dioxid, and salts of various kinds, in what we call living matter. These compounds are also found out of all connection with living objects. So we may say that living matter is fundamentally the same as non-living matter, so far as its ultimate chemical elements are concerned.

Living and non-living matter alike have weight and form, and other physical properties which might be mentioned. They both undergo chemical changes, and in doing so develop energy or store it, as the case may be.

There are indeed so many points of agreement between them that the question has been raised as to whether there is any *constant* distinction that will serve to separate the living from the non-living.

47. **Practical Exercise.**—Refer to some elementary text-book of chemistry for a simple description of some of the properties of the elements and compounds mentioned in the preceding section, and in those that follow.

48. **Distinction Between Living Matter and Living Objects.**—In the study of living things most students will

recognize that some of the parts of living objects are not themselves alive. For example, the last year's leaves of the white oak are not living, although they may still be on the tree late in the spring. Similarly, the outside bark of a large tree has many layers that are not living, and the heart-wood of such a tree is not alive. In our own case, the enamel of the teeth is not living substance, nor is the solid material in our bones, although it is an intimate part of a living object. In the same way, we know that the water and the oxygen in a living body are no more alive than the same substances in the pond or in the atmosphere. So fats and starches, and many other substances found in our bodies, are not living and have never been so. All living objects are thus made up, in part, of non-living matter.

49. How do living objects differ from non-living objects?

As a result of the laboratory work of the last chapter, how do you distinguish living objects from objects that have never been alive? How from objects of the same kind that have been, but are no longer, alive?

The chief differences between living objects and those that have not been closely associated with, or produced by, life are differences (1) in *organization* and (2) in *powers*.

To be organized means essentially to have different parts, which do different work and are bound together in such a way that each part contributes to the whole individual and is, in turn, supported by the other parts.

Organization in living objects may be treated under three phases: (1) gross organization; (2) cellular organization; and (3) protoplasmic organization. The powers and activities of the living objects are believed to grow out of their organization.

50. Gross Organization.—It is not the purpose here to discuss all the organs and parts that appear, with a little study, to belong to animals and plants. It is sufficient to notice that there is a tendency among living things to become bounded by curved surfaces, to have different structures developed at different parts of the body, which enable us to distinguish one end, or surface, or side, from the others. This differentiation is essential to organization and is one of the most marked features of any object that has been produced by the agency of life.

FIG. 2.

FIG. 3.

FIG. 2.—Diagram showing "organization" within the cell, and something of the structure of the protoplasm, as it might appear while living. *a*, alveoli or spheres in the semifluid substance; *c*, centrosome; *cy*, cytoplasmic (protoplasmic) meshwork, containing granules; *nu*, nucleus; *n*, nucleolus; *v*, vacuole; *w*, cell wall.

FIG. 3.—Diagram showing the principal parts of the cell as it appears after it is killed with chemicals. The protoplasm shows more of a meshwork (*cy*). The spaces represent the alveoli. *f*, formed substance in the alveoli. Other letters as in Fig. 3.

Questions on Figures 2 and 3.—If these cells are in reality 25μ in diameter, how much are they enlarged in the drawing? (μ is $.001$ mm.). Identify the various structures mentioned in section 51.

51. Cellular Organization.—In all our larger organisms the differentiation does not stop with this surface condition. Living objects, above the very lowest, are made

up of certain complex units which we call "*cells*." These cells are microscopic in size, and while they are not just alike in different organisms nor in different parts of the same organism, they have certain definite parts which are reasonably constant. See Figs. 7 and 8 for some types of cells and for the elements of structure which they show.

The essential part of the cell is the contents, or *protoplasm*. It is usually bounded and protected by a *cell wall* (Figs. 2 and 3) which is secreted by it. The *nucleus* (Fig. 2 *nu.*) is a differentiated part of this protoplasm, apparently.

In the lowest animals the whole organism is made up of just one such cell. The highest organisms all begin life as a single cell. Thus we see that the single cell is capable of life, and that the real differences between living and non-living things depend on the cell and its substance.

52. Protoplasmic Organization.—Notwithstanding the minute size of cells, it must not be supposed that the protoplasm which forms it is a simple substance. It is the most complex substance known. Indeed, it is not to be considered as a single substance, but rather as a complex mixture of substances, which are continually bringing about changes in one another. Some of the different kinds of substances known to be common in protoplasm are water, inorganic salts in solution in the water, starch, sugar, fats, proteid compounds similar to white of egg, ferments, and waste products like carbon dioxide and urea.

Most of these substances cannot be considered really living materials. The water and starch and urea cannot be

alive. If it is proper to speak of any particular part of the substance being alive, it could only be the *proteids*. It may be, however, that life is rather the result of the intimate relation and interaction of these various substances than the property of any single one of them.

It is thus to be seen that protoplasm is complex in its make-up, both chemically and physically.

53. The Properties of Protoplasm.—It is believed that the peculiar activities of living objects arise out of the activities of the cells, of which the organism is composed; the activities of the cell arise from the activity of the protoplasm which is its essential portion; the special activity of the protoplasm springs from the properties of protoplasm; and the properties of protoplasm are in turn dependent on the chemical and physical constitution of protoplasm detailed in the preceding section. It is believed, therefore, that the differences between organisms, and between the powers of the various cells of the same organism, are due to differences in their different protoplasm—physical and chemical differences that we cannot detect by the microscope or by chemical analysis.

Because the living substance (protoplasm) is so complex, chemically and physically, it is *unstable* and subject to continual change. While this is true in some degree of all substances, it is markedly true of protoplasm. It is so unstable that the very effort to analyze it destroys the particular organization and power that we call life, and decay ensues at once.

This instability of protoplasm gives rise to a most interesting and important property which we call *irritability*. By irritability is meant the fact that protoplasm

may be aroused into action by a *stimulus*, which is not sufficient to injure it, in such a way as to put forth more energy than is involved in the stimulus itself. For example, light, gravity, or a mild chemical action or a touch may bring about a response on the part of the living object, or on the part of the cells of which it is made, much more powerful than could be accounted for directly by the stimulating force.

There is no non-living substance in nature which possesses this quality in anything like the degree that protoplasm shows it.

54. The Powers and Activities of Protoplasm (and of Living Objects).—The chief difference between a living animal and one that is just dead is apparently not so much one of organization as of powers. The animal still has its shape, its organs, its cells; and its cells even seem, on examination, to have their characteristic form and contents, but the peculiar irritability and the activity and powers of protoplasm dependent on it are gone. Chief among these common powers of living protoplasm are the following:

a. The power to change certain foreign materials into its own substance, and thus to produce growth of an internal and intimate sort. This is in contrast with the growth of a crystal or a bed of sandstone which takes place merely by adding, externally, substance already like its own.

b. Power of adjustment to external conditions, through its irritability to external stimuli and its power to respond to them.

c. Power of undergoing an orderly cycle of life, including birth, youth (growth), maturity (reproduction),

and death, as against a more permanent or, if changeable, a less definite, condition of existence.

d. The power to use oxygen in the breaking up of some of its compounds and of utilizing the energy derived therefrom directly for the well-being of its life.

55. Summary.

1. It will be necessary for the student to know something about the following kinds of matter:

a. Non-living.

Entirely unassociated with life—unorganized: inorganic.

Organized:

Merely associated with life, never having been alive (starch, shells).

Matter formerly alive, but now dead.

b. Living: plants and animals.

2. All living *objects* are made up of combinations of living and non-living *materials*. Even the living matter is made up of elements which are found in nature in a non-living form.

3. In general, the structural differences between living and non-living objects may be expressed as follows:

a. Gross organization, including the facts of general form and the presence of organs and systems of organs to do specific work.

b. Cellular organization. This refers to the fact that all living objects consist of one or more cells, or units of structure, which have a general uniformity of character in spite of their great variations in size, shape, and powers.

c. Protoplasmic organization. This refers to the con-

stant presence in organisms of a fundamental substance which seems absolutely essential to life. This substance is chemically very complex and unstable. It is the essential part of every living cell.

4. Associated with these facts of structure, living matter is further characterized by the following powers and activities:

- a. It is highly *irritable* and easily stimulated by external conditions, and has power of adjusting itself to these conditions.
- b. It has the power of increasing itself by use of substances unlike itself (*assimilation*), and of growth by introducing this assimilated material within its own structure.
- c. It uses oxygen (*respiration*); and by the union of oxygen with elements in its own substance it manifests energy of various kinds (as heat, motion, nervous energy, and the like), and makes waste material which must be eliminated.
- d. It has the power of dividing, and thus of reproducing its kind by the multiplication of individuals.

56. Supplementary topics for themes in Zoology and English.

1. The activities and powers of plants and animals.
2. The chemical constitution of protoplasm.
3. Theories as to the physical structure of protoplasm.
4. The life cycle of some selected organism. Why "cycle"? The essential steps or stages in it.
5. The difference between the growth of a crystal and of an animal.

6. Justify the statement that irritability of protoplasm is at the foundation of all the life activities.

7. Why are the chemically complex organic substances likely to be unstable? Why does this fit them to be used as foods?

57. Words to be derived and defined.

Organized; protoplasm; assimilation; instability; stimulus; oxidation; chemical element; chemical compound.

CHAPTER VI.

LABORATORY EXERCISE: FORMS OF LIFE.

58. Allow the student to collect several different types of living objects, together with all the facts he can find with respect to their food and modes of living.

The teacher should see that such organisms as the following are brought to his attention: *fungi*, such as toadstools and shelf-fungi; *bread mold* (which may be grown on bread, in a moist chamber formed by a bell-jar inverted over a plate); *bacteria* (which may be grown rapidly by chopping up some hay and placing it in a vessel of water with a small piece of meat the size of a cherry); *pond-silk*, which floats at the surface of quiet ponds; *corn* and other common plants; any animals, as the *earth-worm*, the *frog*, the *cow*, and *man*.

Study these objects somewhat as in Chapter IV.

59. Organisms may be classed as follows:

1. Those organisms able to subsist on inorganic food.
2. Those organisms requiring organic food.

Do 1 and 2 together include all possible organisms? Reasons for your answers. Could an organism possibly belong to both at once? Why? Be very careful here: many students are inclined to go astray at this point.

Which, if any, of the forms of life mentioned and studied in Section 58 seem to you to belong to the first class? Which to the second class?

Let the teacher, by questioning, bring out what the pupils know about the food requirements of the plants and animals mentioned above, adding, when necessary, facts which will extend the students' knowledge of the experiments that have been made by others. The time is too short for the pupils to verify the water-culture-medium experiments; but the teacher should make the student realize, as though he had made the experiment himself, that the

pond-silk or the wheat or corn may be nourished, through its complete life cycle, by a water-culture in which the necessary inorganic compounds have been supplied in proper proportions—together, of course, with atmospheric air—without any organic matter whatever. The student will know that these plants ordinarily avail themselves of the decaying organic matter in the soil.

A demonstration of living bacteria should be made under the highest power of the microscope, and the odor of the solution in which they are found should be noted. What does the odor indicate? Why does not meat, which has been properly canned, have this odor?

Similarly, the habits of the molds and their effect on the bread should be studied. Where have you seen molds in nature? Enumerate all the substances on which you have seen them growing. What kind of substances are they? Have you any evidence that the mold is actually disorganizing the bread? Is it fair to infer that it uses the bread in its growth? How would you test whether the mold actually *must have* organic food? Have such tests ever been made?

In a similar spirit study the food necessities of all the organisms under consideration, and state clearly the facts.

60. Compare all the forms that you have classed under group 1; similarly those of group 2. Have the 1's anything in common, of structure or appearance, other than this food requirement? Have the 2's?

61. **A Second Classification of Organisms.**—Organisms are commonly classed as:

A. Plants.

B. Animals.

To which of these groups do the various organisms you have been studying belong?

62. **Compare** this classification with that in Section 59.

Is this a true equation— $1 + 2 = A + B$?

Is 1 the exact equivalent of either A or B? Is 1 greater or less than A? Is 2 greater or less than B? Give your grounds for your various answers.

If you should divide the group of plants into $A = A^1 + A^2$, in which A^1 equals green plants and A^2 the non-green plants, could you make $1 = A$ true by adding or subtracting A^1 or A^2 ?

Translate these expressions into a plain statement of truth and see if they hold good so far as your observations and information go: $1 = A - A^2 = A^1$; also $2 = B + A^2$.

Devise some sort of a diagram to express the truths indicated by these algebraic formulae.

Where would the *mistletoe* fall in the classifications you have been making? Why?

63. **Exercises for Further Research.**—1. Make a classification of the organisms you know, on the basis of their food relations; that is, as to whether they can be independent of organic food or not; and if they must have organic food, whether they use vegetable food or animal food; whether they use dead or living food; whether they are parasites, semi-parasites, or predatory forms. Where would man fall in this classification?

2. Are bacteria plants or animals? What grounds do you have for your answer? To what facts do these other terms, applied to the same organisms, refer: *germs*, *microbes*, *organic ferments*?

CHAPTER VII.

PLANTS AND ANIMALS.

64. We have no difficulty in distinguishing the cow from the clover she feeds upon; nor the bee from the flower that it visits. They differ much, both in their outward form and in their internal structures. But even these organisms, with all their differences, have much in common: they are alive, which is the most important thing that can be said about them; they use food; they grow; they are organized; they are made up of cells and of protoplasm; they reproduce; they die; and when they die they decompose into similar inorganic constituents.

65. **Doubtful Forms and their Meaning.**—As we consider the lowest plants and the lowest animals, microscopic forms, it is even more difficult to frame our definition of plants and animals in such a way as to make a satisfactory division. Indeed, there are some forms of organisms which we cannot surely call either plants or animals.

This would be surprising and disconcerting if we consider that the plant and animal kingdoms were created perfect and distinct as we now have them. If, however, they are really kin to each other, and are merely different kinds of living things, derived from a common stock by long growth and gradual change, then this condition is exactly what we should expect. The dia-

gram (Fig. 4) will give the student an idea of the relation between the kingdoms.

66. The Popular Distinctions Between Plants and Animals.

—We often think of motion or locomotion as a power possessed by animals alone; but this is not a sufficient distinction, for all plants have some parts capable of

FIG. 4.—A diagram to suggest the relations between plants and animals.

Questions on Figure 4.—In what respects are fungi intermediate between green plants and animals? Mention some of the doubtful organisms which are difficult to classify strictly as plants or as animals.

motion, and some of the lower plants are gifted with the power of locomotion, as in many of the lowest water plants. Furthermore, many animals, fairly well advanced in the scale of life, are fixed and do not have the power of locomotion in the adult stage. This is true of the corals, some of the echinoderms, and the tunicates.

Again we have some unicellular organisms that have

the green coloring matter (*chlorophyll*), which we think of as being confined to plants; and yet these green cells have the power of definite locomotion, such as is thought of as confined to animals. Such a mingling of characteristics is very confusing. It is not possible to say that these organisms are clearly plants or animals. It is better just to recognize that the two kingdoms are related and that the relation shows most in the simplest forms.

Many people would doubtless think of a nervous system and sensitiveness as being one of the features separating animals from plants. But all plants are sensitive in some degree to all the chief external stimuli; and many animals have no more signs of a nervous system than do the plants.

Indeed, there is no single statement that is true of all animals which does not include some plants; just as there is no single statement that includes all plants which is not equally true of some animals.

There is this, however, in these popular distinctions: it is true in a general way, that animals are more motile, and more sensitive, and must have more complex foods than plants. In consequence, special tissues and organs are developed in most animals for these purposes, as the muscular, the nervous, and the digestive systems, which are relatively lacking in plants.

67. The Relation of Plants and Animals to the Foods.—In Section 46 was enumerated a list of the chemical elements which are commonly found in protoplasm. These, therefore, are the elements that must be had by organisms as food in order to build up protoplasm and to do the work of life. All of these elements occur in such forms

that they may be readily taken up and used by plants and animals alike, except the carbon and the nitrogen. The iron, potassium, sodium, sulphur, phosphorus, and the like may be had in solution in the water that percolates through the soil, from which it takes up sufficient quantities for either plants or animals. Oxygen can be had from the air and can be used thus as free oxygen; in addition, it can be had in various common compounds, as water itself. Hydrogen also is found in connection with oxygen in water (H_2O).

Free nitrogen is abundant in the air, of which it constitutes about 80 per cent.; but most organisms, both plant and animal, are wholly unable to use it in this form. There are some bacteria that seem to have the power of taking up free nitrogen and of building it up into living substance. Nitrogen occurs also in nature, inorganically, in compounds known as *nitrites* and *nitrates*. Plants have the power of using nitrogen from this source. Animals, on the contrary, lack this power of using inorganic nitrogen and must get their nitrogen in the form of *proteid* substances, which are formed by organisms and consist of carbon, hydrogen, oxygen, and nitrogen in combination. We are familiar with this fact in our own dieting, when we say that we must have eggs or lean meat or beans, in order to get the necessary nitrogen compounds.

Carbon occurs in the pure state, as in graphite or charcoal. It occurs in the atmosphere in union with oxygen as carbon dioxide (CO_2); it is found also in various organic compounds, as starch, sugar, fats, and the like, in combination with hydrogen and oxygen; and in the proteids, the most complex of all foods. None of the organisms can use the carbon in its pure form. Only green plants can use it in the form of CO_2 . All organisms can

use it after it has been built up by other organisms into complex substances like sugar and proteids.

68. This relation of the living things to these two important elements in the food supply may be put more directly from still another point of view.

Green plants (organisms possessing *chlorophyll*) can, under proper conditions of sunlight, take up the gaseous carbon dioxide of the atmosphere, unite it with the hydrogen and oxygen in water, and build it up into starch of its own. Using this starch, such a plant can take the inorganic nitrogenous compounds of the soil (only in rare instances the free nitrogen of the air) and build up protoplasm or any other complex substance which it needs, without any organic food at all. In other words, such plants are most nearly independent of other organisms.

Fungi, or the non-green plants, can do the same, provided they are supplied with the starch or sugar. That is to say, they can get their nitrogen from inorganic sources, provided their carbon is supplied in an organic form. This is the reason that the yeast plant, which is a *fungus*, must be supplied with some starch or sugar for its growth. These forms are found as *parasites* or *saprophytes* on organic matter.

Animals must have both their carbon and nitrogen in organic form; that is, in complex and unstable compounds, like starches, fats, and flesh or its equivalent in vegetable protein. Animals are thus seen to be most dependent on organic sources of food; green plants least dependent; and the fungi are intermediate between the others.

69. Summary.

1. Plants and animals agree in so many respects that we must regard them as being fundamentally alike. The

differences between them are less important and less constant than the similarities.

2. It is not possible to frame any single definition that will completely separate all plants and all animals. It is at the apex of the V (Fig. 4) that the difficulty is greatest. This is taken to point to a real kinship between plants and animals.

3. In general and allowing for certain exceptions, the following parallel column arrangement will suggest the chief differences between the two great groups of organisms:

Plants.

1. Possess chlorophyll.
2. Can manufacture the complex substances from CO_2 , H_2O , and other inorganic compounds.
3. Work of plants is largely a building up of complex, unstable substances and a storing of energy. Little tearing down and hence little activity.
4. Sensation and motion, when present, general rather than by special organs.
5. Cell walls usually more rigid and composed of cellulose or some modification of it.

Animals.

1. Do not possess chlorophyll.
2. Must have complex organic foods, as starch, fats, and proteids "ready made."
3. Work of animals largely a tearing down of unstable compounds produced by other organisms. More activity.
4. Specialized organs and tissues for sensation and motion (muscular and nervous tissues) quite characteristic.
5. Cell walls not so marked; cells more intimately fused. Not cellulose.

4. Fungi stand intermediate between green plants and the animals in respect to food and nutritive powers. Animals must get both carbon and nitrogen from organic sources; green plants may get both from inorganic sources, but of course may also use them in organic form; fungi must have its carbon from organic, but may get its nitrogen from inorganic matter.

70. Special topics for themes in Zoology and English.

1. Motion and locomotion in plants.
2. Stationary animals and their manner of life.
3. Show that sunlight is really the source of the energy shown by all organisms.
4. Why do not plants have special digestive organs, since animals have them?
5. What are the results in an organism that come from breaking down a complex unstable union of carbon, hydrogen and oxygen (such as sugar) and forming more stable and simple substances, such as CO_2 and H_2O ?
6. Find formulas of some nutrient medium, such as Pasteur's solution. What is organic and what inorganic about it? Will it nourish yeast plants? Why? Will it nourish animals? Why?
7. What kinds of life probably appeared on the earth first, plant or animal? The reasons for your conclusions?

71. Define and derive the following terms:

Locomotion; chlorophyll; sensitiveness; nitrate; nitrite; proteid; fungi; saprophyte; parasite; cellulose.

CHAPTER VIII.

A REPRESENTATIVE ANIMAL: THE LOCUST OR THE CRAYFISH.

72. Most pupils in the country schools or in the small towns will know in a general way where to find either of these animals. Either will serve very well as an introductory type; but the writer prefers the locust for field work and the crayfish for the laboratory study. *If there is not time to study both animals, one portion of the class might well study one and the rest the other.* This would make it possible to compare the two, point by point, in a manner that will be highly valuable.

In city schools particularly some means for giving the animals a reasonably natural home in the laboratory should be devised. Crayfish can be kept indefinitely in aquaria; and the grasshoppers will thrive for sufficient time in large boxes in which are kept some of the plants necessary for their food. Wire screening over two sides of the box will make it possible to watch them continuously.

The Locust ("Grasshopper"; any large species).

73. **The Field Exercises.**—This should be done early in the fall, if possible, and the studies should actually be made in the field by the individual pupil. The following outline will indicate to the student some of the more interesting topics for study.

A. *Habitat and Habits of Life.*—Where do you find the locusts most abundant? Is their number or activity affected by temperature? By moisture or drouth? Evidences. Examine on different kinds of days, and compare. When, during the day, are they most active? What about them at night?

Do they show any preference for any particular type

of plant? What parts of the plant do they frequent? Do they seem to injure the plants in any serious degree? Do you ever find them in trees or the higher vegetation? Do they show any disposition to hide? Do they seem to have any enemies? If so, what? In what various ways do they seem to be able to escape possible enemies?

B. *Variation*.—How many different kinds of locusts are you able to find? In what respects do they differ? Do you think they are of different species, or merely different ages of the same species? On what grounds do you base your conclusion? Would the male and female probably be alike? Find both (if necessary refer to the books to verify your results). Make a study of the color element and its variations in your species. Is it general, or in pattern?

C. *Sensitiveness*.—Do they recognize your approach? Evidences. If so, is it through hearing, or jar, or seeing, or otherwise? Reasons for your view? Do they recognize each other in any way? Describe their behavior carefully, under various tests that you may be able to devise, and interpret their actions.

D. *Locomotion*.—In what various ways do grass hoppers get from place to place? Under what circumstances do they use each of the different methods? How do they move when disturbed? When undisturbed? Experiment upon the matter? What is the more commonly used method of locomotion? What organs are used in each of the methods and how are they used? Describe in detail. Just how do they climb? What position do they take on the plant? How far do they usually fly? Can this distance be increased appreciably? How far can

they jump, in terms of their own length? Place one in water. Observe and describe the result.

E. *Other Activities*.—Do they make any noise at all? Under what circumstances.

How is feeding effected? Catch a large specimen and try to feed him. Describe and interpret all the observed phenomena. How do the jaws work?

Do you find any evidence of egg laying? If so, what are the conditions—number, place of laying, arrangement of eggs, etc.?

F. *Collections*.—Each student should collect and take to the laboratory, for his own use, several specimens of each sex—the largest he can find. Some of these should be preserved in alcohol or formaldehyde for dissection later; the others should be properly cared for and studied alive in the laboratory for further details of external structure and behavior.

74. **Laboratory Studies**.—The time at the disposal of the class must determine how much of these studies shall be undertaken. If time is limited, they can be divided among the members of the class.

A. *Activities*.—The great gain of the laboratory, in studying the activities, is that one can control the conditions and thus get exactness of results which cannot come from more general observation. This use of controlled conditions we call an *experiment*. In this way the field observations can be extended and corrected. This testing of one's result is an exceedingly valuable training.

In any experiment the following steps should be taken:

1. State in writing just *what you wish to determine*.
2. State the *steps you propose to take* in getting your information, and why you take each.
3. State your *observed results* simply as matters of fact, without any reference to the conclusions to be drawn from them.
4. *Make the inferences* that you think are supported by your facts.

a. *Sensitiveness*.—(Much interesting work may be done in respect to sensitiveness. If time allows, it is excellent exercise to devise original experiments in order to test the presence or absence of a given sense.)

See if you can get them to feed by placing the edge of a leaf close to the mouth of a specimen that has not eaten recently. Afterward dip the edge of the blade of grass in a salt solution and note the results. Does he recognize any difference? Evidences? Try another specimen with another blade of grass dipped in a solution of quinine. Note and interpret results. Try still other materials.

Devise experiments to test whether they are sensitive to odors. If so, where is the sense located? Evidences.

Are you sure they are sensitive to light? How many proofs of your conclusion can you advance? Can they distinguish colors at all? How can this be determined? Are you sure that your experiment really tests it? Do the two eyes cover wholly different fields? Is there any part of the field that the animal cannot see without changing position? Evidences.

Similarly, devise experiments to determine whether

they have a sense of touch. Of hearing. Of temperature.

Assuming that they have these various senses, can you determine which he uses in the selection of his foods? Which does he depend upon most in taking care of himself; for example, in escaping you when you are trying to capture him?

- b. Can you discover by observation and experiment the range of their food? What do they prefer? Have they anything like hunger? How do you judge? Watch the feeding process carefully and describe the natural position which the locust takes in reference to its food and the mode of action of the mouth parts. Notice the secretion ("saliva") that escapes from the mouth when the insect is handled.

- c. Study more carefully the locomotion, and the exact method of accomplishing it. Just how are the various appendages used in the process? To what extent do the various parts of the body move in relation to each other? To what extent the various segments of the appendages?

Do you find any motions that you would be disposed to class as "breathing" motions? What evidences would you advance that they are respiratory? Where are the motions located? Can you discover any organs by which the air might enter the body? Count the motions per minute, both before and after a long flight.

Find some way to measure the strength of the action of the jumping legs.

B. *The form and structure.*

1. The general plan of the body.

- a. *Symmetry*.—Is there any plane which would divide the body into symmetrical halves? If so define its position. Is there more than one such plane?

If we imagine an axis drawn lengthwise along the middle of the animal we would call this axis the *anterior-posterior* axis. Are the two poles of this axis alike or unlike? Enumerate all the differences you can find between the anterior part and the posterior part—as shape of body, and the like. What organs are found at the anterior end? The posterior end?

What is the *prime* meaning of *anterior*? What advantage is there to the animal in having these organs at the anterior end? Why do you think these particular organs have come to lie at the anterior end rather than elsewhere? Similarly, imagine an axis perpendicular to this principal axis, and extending from the back to the belly of the animal. This is called the *dorso-ventral* axis. Are its ends alike? Enumerate all the differences you can find between the dorsal and ventral surfaces of the body. What are the advantages in having the wings, etc., dorsal? the legs and mouth-parts ventral?

In the same way think of a line perpendicular to both of these and extending from left to right. Are its poles alike or unlike? What value is there in this condition? What organs are thus duplicated, or paired?

The condition which you have studied out in the grasshopper is known as "*bilateral symmetry*." Undertake to define this kind of symmetry. What advantages are there in this kind of symmetry to the animal possessing it? Why would we expect the anterior end to be different from the posterior end; that is, what *causes* would tend to make it so? What would make the dorsal surface different from the ventral? What facts would tend, in the long run, to make the right and left sides duplicates? Be sure to distinguish carefully between the evolutionary *causes* of bilateral symmetry and the *advantages* of it after it is once produced.

- b. *Segmentation*.—By segmentation in animals we mean the tendency to repeat similar structures in line, along the principal axis—as vertebræ, ribs, legs, etc. Parts are repeated on opposite sides of the body, as we have seen, but this is not segmentation.

What external signs of segmentation can you find in the locust? How many such segments do you think the animal has? Enumerate all the kinds of organs or marks that show this tendency to repeat structures. Which show it most strikingly in the *thorax* (or body) region? Which in the *abdomen* (the softer posterior region)? Are there any rings showing the actual division of these segments? Where do they show to best advantage? Do the appendages assist in any way in indicating the number of segments?

Note the three general body regions: *head*, *thorax*, and *abdomen*. How are they related to each other in size, shape, and attachment? Is there a "neck," or "waist"?

How many segments can you find in each of these regions? Are they equally clear and distinct in the three? Are they equally clearly seen on the back, belly, and sides? What grounds have you for considering that the head is not just one segment and the thorax another? Make a drawing of the side view of a locust, without the legs and wings. Enlarge two or three diameters.

2. Special Structures.

- a. The carapace and openings. Examine the external covering of the animal. Would you call it "skin"? Why? Is it uniform in thickness and hardness in the various parts of the body? State the facts and give your interpretation of the facts.

Is each segment covered with one continuous ring or is there an indication of a distinction between a dorsal portion and a ventral portion? Compare the various segments.

Openings in the carapace: locate, in relation to the segments, the mouth, anal opening, *spiracles* (the openings of the breathing apparatus). How many pairs of spiracles? Why so numerous? (See text-books.)

- b. Appendages. Begin with thorax.

How many pairs of legs? What similarities and differences do they show? How are they attached to the body? What is their position in relation to the main axis of the body; that is, do they belong to the anterior half or the posterior half of it? Examine under a hand lens and draw, showing all the parts. How many segments in each leg? Determine the movement possible to each joint.

What is the natural position of the wings when at rest? What is their position in flight? How many pairs? Where attached to the body? Are they nearer the dorsal or ventral surface? Nearer the anterior or posterior end? Do you

see any advantages coming from this position, rather than further back or more ventral? Compare the wings with the legs. Are they made up of joints as the legs are? Compare the front and rear wings as to structure. Examine under lens and draw both wings,—showing size, shape, the position and branching of the “veins” or ribs. How do the front and rear edges of the wings compare? Of what value is the difference?

Look carefully over the abdominal segments, particularly the posterior ones. Do you find anything suggesting appendages? Are they the same in all specimens? Can you suggest their function? See text-books.

Examine carefully the whole mouth region, first with a naked eye and then with a hand-lens. Watch the mouth parts in action. Move the various structures with a needle. Are the structures paired or median or both? Describe the parts in front of the mouth; behind the mouth; at the sides. Make a diagram with the mouth in the center and the parts grouped about it and far enough apart to enable you to show their relation, as you understand it. What is the part played by each in eating? Mention the points at which the mouth parts appear to you well adapted to the kind of food used by the locust.

Compare your drawing with figures in the reference books for the names of the various mouth parts. Are they segmented like the legs? Are there any other paired appendages about the head? If one pair of jointed appendages represents a segment of the body, how many segments in the head of the locust?

c. *The Sense Organs.*—The antennæ. What is their position? Are they segmented? What do you believe to be their function? Evidences.

The eyes. These are not appendages in the same sense as the antennæ, although they are paired. Note their exact situation and size. Examine their surface with a lens. Estimate the number of *facets*. What is the shape of each facet? Why this shape? What does each facet signify (see descriptive texts)? Estimate again the amount of the whole surroundings commanded by the two compound eyes. There are also three simple eyes (*ocelli*). Find them. Make a drawing of the head from the front view, showing the structures studied.

The "ear." Examine the first segment of the abdomen for the ear sac. It has a membrane or drum stretched over it. Structures are said to be *homologous* when they are fundamentally the same, even though they may have very different appearance and uses. According to this definition, would you consider the segments homologous? Are the three pairs

FIG. 5.—A diagram showing the digestive tract and some of the other internal organs of the locust. The digestive tract is represented as sectioned. The regions of the body are: head (*hd*), thorax (*th*), and abdomen (*ab*). *a*, antennæ; *b*, brain and its chief nerves; *c*, colon or middle part of intestine; *ce*, cement glands; *d*, duct of the salivary glands; *e*, excretory tubules which open into intestine; *g*, gizzard; *g.c.*, gastric cæca; *h*, heart; *i*, ileum or front part of intestine; *m*, mouth; *o*, oviduct; *ov*, ovaries; *p*, pharynx; *r*, rectum or hinder portion of intestine; *s*, stomach; *s.g.*, salivary glands; *v.g.*, ventral line of ganglia; *w*, body wall, made up of cuticle, skin, and muscle.

Questions on the Figure.—Enumerate regions of the digestive tract, and study the differences. Can you make out the probable special functions of any of the regions? What would you suppose to be the function of the gastric cæca? Evidences? What is believed to be the function of the tubes (*e*) opening at the union of stomach and intestine? Compare the diagram with your dissections and with other figures so as to realize that the organs are not so clear in reality as in a diagram. What do you understand by "diagram"? What are its strong and what its weak points?

of legs homologous? Are the antennæ homologous with legs? Are the mouth parts? Are the wings? Give the reasons for your answer in each case. Compare your conclusions and reasons with those of the writers of the books.

- d. *Internal Organs.*—If it is desired to dissect the locust and study the internal anatomy, the student will find detailed instructions in the reference text-books.

The writer suggests that only a general identification of the larger organs be made, and that the internal anatomy of the crayfish be taken up with some thoroughness instead. The crayfish is larger and the organs can be more readily identified.

With some care the following sets of organs may be identified in the grasshopper (see also Figs. 5 and 6).

The digestive system: note its regions, the outgrowths of these, and the probable function of each. (The excretory system is associated with the digestive.)

FIG. 6.—Diagram of cross-section of locust in posterior part of thorax. *ap*, first joint of leg; *bw*, body wall, made up of cuticula, skin, and muscle; *c*, gastric cæca; *h*, heart; *l*, spaces in body cavity occupied by air sacs, fat bodies, or blood; *s*, spiracle opening into the tracheal tubes (1-3) which carry the air to the various parts of the body; *s.g.*, salivary glands; *v.g.*, ventral ganglion; *w*, wing.

The respiratory system—consisting of the spiracles which are external, the tracheal tubes, and the air sacs. These glistening tubes make a very complex network, going to all portions of the interior.

The circulatory system. It is not easy for the beginner to get a satisfactory view of this. The heart is dorsal and is so close to the body wall that it is likely to be removed with it in dissection. It is much elongated, extending the length of the abdomen. The other blood vessels are rather indefinite spaces.

Reproductive system. This differs, of course, in the male and the female. The female has a pair of *ovaries* filling a large part of the posterior segments of the abdomen. These produce the eggs, which reach the exterior by way of tubes known as *oviducts*. The *testes*, or *spermaries* of the male correspond to the ovaries—and produce the *sperm* or male cells. These escape to the outside by delicate ducts. Eggs are fertilized while still in the body of the female, and receive afterward certain protecting and cementing materials from the walls of the female tubes.

Nervous system. This is ventral and runs the length of the body. It is made up of a series of *ganglia* or *nerve centres*, connected in a chain by *nerve fibres*. This chain is made up of three regions: (1) a ganglion above the gullet which is called the brain; (2) a loop of nerve fibres about the gullet connecting the brain with, (3) a chain of ganglia scattered along the length of the floor of the thorax and abdomen. What is probably the special function of each of these regions?

The Crayfish (any Species).

The questions asked for the grasshopper, with such changes as would be suggested by the common sense of teacher and pupil, will serve as a general guide for the study of the crayfish. The mode of life is very different, but the same general problems of life are to be solved by both animals.

75. Suggestions for field and laboratory studies.

1. The general conditions of life. To what extent does it use land? to what extent water? Is it heavier or lighter than water? How is it affected by drouth and by heat and cold? What is its food? What are its enemies? How does it protect itself or avoid or escape them? Has it any devices of concealment? How does it behave when disturbed? When stones are turned over? How does it behave when you try to grip it? Is there any point where you can safely hold it?

Discover their burrows in low moist places. What becomes of the dirt from the burrows? How are the burrows formed? Dig out one and follow its course. How deep? Does it contain water? or crayfish? Do you ever find any empty shells of crayfish? What may they mean?

2. *Activities*.—In field and laboratory find all the facts obtainable with respect to methods and efficiency of locomotion; feeding; reproduction; respiration.

3. *Sensitiveness, Kinds of*.—Experiments (similar to those suggested for the locust) should be devised to prove whether they are sensitive, and, if so, what special senses they possess and the location of the organs.

4. *General Form*.—Work out its symmetry as indicated for the locust. How do the general body regions compare with those of the locust? Has it head, thorax, and abdomen? Does it show segmentation? How does it compare in this respect with the locust? Study with care the external evidences of segmentation, the number of segments, their freedom and degree of fusion in the various regions.

Make outline drawings of the body from dorsal and ventral views.

5. *The Appendages*.—How do these compare with those of the locust in number and variety? How many, and how many kinds, do you find on first examination?

The adaptation of the appendages. After this much of study go back to the living specimen and watch the natural action of each type of appendage. Which seem to be least used? Which seem most used? Describe carefully the uses of all so far as you can make them out. Note the particulars in which the form and structure of

each seem to be specially suited to the work which it does. Find what advantages accrue from having the different types where they are rather than elsewhere.

Are the four walking appendage *shomologous* (see p. 64) with each other? Are the large nippers (*chela*) homologous with these? Evidences? Are the small abdominal *swimmerets* homologous with one another? With the walking appendages? What observations and arguments can you advance in favor of the view that *all* these paired appendages are homologous? What against such an interpretation? What is your real conviction in the matter? What arguments can you advance to support (or to combat) a view that a pair of appendages indicates a segment of the body, no matter where they are found?

Remove the arch of the carapace on one side of the thorax and expose the gills. Cover the animal with water and float the gills out so that you can study them in place. Are they related in any way to the appendages? In what way? With how many appendages are gills found? How many gills to each appendage? What is the structure of the gill? Examine under the lens and draw one gill.

Remove the appendages in front of the chela, one at a time, being careful to get the entire appendage. How many kinds, and how many of each kind, do you find? Try to determine their possible use. Make a careful drawing of one of each kind of appendages, beginning with the abdominal ones and going forward. Study the tail. Is it a segment with appendages? Has the last segment of the body any appendages?

Classify the appendages of the crayfish according to the following scheme. Carry out your analysis until only those that are clearly alike are found together.

Where, in your scheme, would the following terms fit: *swimmerets, chela, walking appendages, mandible, maxillipeds, maxillæ, antennule, antennæ*?

Appendages	{	Pre-oral	{	How many, and of what kinds?
		Mouth parts		
		Post-oral		

What is your final judgment as to the total number of segments in the animal?

Compare the appendages throughout with those of the grasshopper. Are they more, or less, differentiated and specialized?

6. *Internal Anatomy*.—With strong-pointed scissors, cut through the skeleton along each side of the back, the whole length of the animal. Be careful not to cut deep enough to injure the organs beneath. Remove the part of the shell between the cuts very gradually, and cut the attachments in such a way as to leave all the soft parts in place. Some of the epidermis, which produces the shell, will probably be removed with it. Remove what is left after noting its texture and color.

Study the following structures:

a. *Muscles*.—Examine the harder masses of flesh in the abdomen and forward. Tease out a small portion and examine it under the microscope and see if it shows the structure of muscle (see Fig. 25). In what directions do these various muscle fibres run? Examine closely and see where some of them are attached. What would be the result on the parts of the body from their contracting? How many of such muscles do you find? After the other organs are removed examine for still other muscles, if time will allow. How is the abdomen bent downward? How is it straightened? Which are the more powerful muscles? Find the muscles that work the jaws (mandibles); those that work the chela.

b. *The Heart*.—Unless the circulatory system has been injected with a colored mass, little can be seen except the heart. It lies just beneath the carapace, well back in the thorax. What is its

shape? Find the openings into it? Through these the blood enters from the cavity in which the heart itself lies. *Arteries*, which always carry blood *away from the heart*, pass both forward and backward from the heart. A permanent dissection of a lobster in which the arterial system has been injected with a colored mass makes a good supplementary demonstration.

c. *Reproductive Organs*.—These will be found immediately beneath the sac in which the heart lies, as whitish (male) or yellowish to brown (female) lobed structures. Depending on the sex, there will be found:

Ovaries or *Testes*.—Form, position, and number of lobes?

Oviducts or *Sperm Ducts*.—Course, length, and point of outlet? What is the sex of your specimen. Consult the reference texts. Are there any external differences between the sexes?

d. *Digestive Organs*.—Remove the sexual organs, *nothing more*. Liver—a pair of yellowish masses anterior and ventral to the reproductive organs. Do these connect with anything? Stomach—sketch it in position. Notice its shape. Dissect later, opening it from the ventral surface. Note the anterior and posterior chambers, and the grinding apparatus inside. How are the teeth arranged. How do they work in life?

How is the mouth situated relatively to the stomach? Follow the intestine backward from the stomach to the anus. In what segment is the anal opening?

Make a sketch of the entire tract from the side, showing in what part of the carapace each region is.

e. *Nervous System*.—Remove the intestine, cut carefully through the muscles in the midline of the body until the white ventral nerve-chain is uncovered. Follow it forward to the head, cutting away the hard plates that cover it over in the thorax.

How many swellings (*ganglia*) in the abdominal region? What is their relation to the segments? Where do nerves arise? What is their probable use?

Thoracic Ganglia.—Number and relation to the appendages?

Head Ganglia.—Look for one under (*i. e.*, posterior to) the gullet, and another (the *brain*) in front of it. How are these two ganglia connected? Make a diagram of the relation of the nervous system and the digestive tract, from the side.

f. *Excretory Organs*.—The "*green glands*" occur in front of the mouth and in the ventral part of the head. They open at the base of the *antennæ*.

Make a diagrammatic view of an imaginary cross section of the thorax in the region of the heart, and one of the abdomen—showing the relative position of the internal organs. Also a diagram of a mid-longitudinal (*sagittal*) section.

76. Comparative Exercise.—Sum up the points of likeness in the the crayfish and the locust. The points of difference. Keep in mind the degree of union of head and thorax; the number of segments represented in each of the three regions; the degree of differentiation among the appendages; the mode of respiration; food; and general activities and habits.

77. Supplementary Library Work.—After the laboratory and field work has been done the student should be encouraged to follow up some good description of the crayfish or lobster or locust in the reference texts. Let him see to what extent his own observations are supported by those of other people. In case of difference, what should you do, in the spirit of the scientific method?

CHAPTER IX.

THE GENERAL ANIMAL FUNCTIONS AND THEIR APPROPRIATE ORGANS.

78. Animals may be very much simpler than the grasshopper or the crayfish or they may be considerably more complex; but in either case the work which they must do, in order to be successful in life, is practically the same. The differences are chiefly in the way in which the work is done.

79. **What Must an Animal Do?**—In our study of the locusts and crayfish we have found that these animals must have food, and in getting this they must usually be able to move about and to move definitely. In order to move in such a way as to secure food satisfactorily, they must be sensitive to the presence of food and be able to control their motion. Furthermore, these animals have enemies, and they must have some power of escaping these enemies, who are also seeking food, or be able to protect themselves from them or be destroyed by them. For this reason, as well as for getting food, they must be sensitive and able to move.

The soft, living parts of the body must be supported and protected from external influences that might injure, —as cold, heat, drouth, rough contacts, crushing, and the like. Thus we see the value of the hard parts (skeleton), which are so common among animals.

As the result of using food these two animals have the power of growth. Growth, however, does not continue

indefinitely, even though the animal continues to use food. After reaching a certain maturity of size, the animals cease to grow and may reproduce new organisms like themselves. Reproduction merely means that some of the materials which might be used for growth are devoted to making new individuals of the same species.

These activities which have been enumerated for the crayfish and locust are the activities which we shall need to study in all animals. If any animal does not show them, we shall need to know why it does not.

79. A classification of animal functions.

1. Nutrition or metabolism; including the use of food in all its steps, in building up the individual or in producing energy.
2. Protection and the physical support of the soft parts.
3. Growth.
4. Reproduction.
5. Sensation and sensitiveness, including all the powers and activities which enable the organism to adjust itself to its own needs and to the conditions about it.
6. Movement, including locomotion as well as all the smaller movements of parts of the body.

80. How are These Functions Performed in the Simplest Animals?—The simplest animals are microscopic in size, and are composed of a single mass of living material (a *cell*; see §51). The bodies of the larger animals are composed of many such cells united in one body. We have already seen that the essential part of one of these cells is the living substance within—called *protoplasm*. It is a semifluid material which ordinarily has the power

of producing a denser outer portion—the *cell wall* (Figs. 2 and 3, *w*). This protoplasm has all the powers mentioned in the preceding section in their very simplest form. The one-celled animals are very varied in shape

FIG. 7.—Various single-celled animals. 1-4, Rhizopoda; 5, Sporozoa (stages of parasite of malaria); 6-9 free-swimming ciliate Infusoria; 10, a ciliate stalked infusorian; 11, a stalked flagellate infusorian; 12, a free-swimming flagellate form.

Questions on the Figure.—What degree of differentiation can you find among these animals? What suggests that they are animals rather than plants? Compare them in order to give statement to the differences between them—in structure; in possible activities—as motion, taking of food, and the like. By reference to figures of other texts determine what species these are most like.

and size, but they are very uniform in the fundamental work which they must do. A page of such animals will be seen in Fig. 7.

In the very nature of the case there can be no complex

organs such as we have found in the crayfish. In the crayfish these organs are all made up of many special cells, each one of which is potentially equal to the whole animal of the lower types. All the work is done by this living protoplasm. If food is captured it is by the protoplasm. In case there is a cell wall about the protoplasm, the food must be absorbed through it in a fluid form or be taken through an opening in the cell wall. There is no stomach: food is merely digested in, and used directly by, the protoplasm.

The protoplasm has the power of taking up oxygen from the water and of giving off its waste materials into the water, through the cell wall.

This living stuff is sensitive in some degree to chemical conditions of the water and of foods, to light, to gravity, to contacts, to heat, and the like—though there are no eyes, nor ears, nor taste organs. There may, however, be special projections of the protoplasm through the cell wall, and these may be more highly sensitive than the general surface (Figs. 7, 3; or 8, 5).

When the protoplasm is aroused by some outside stimulus the most noticeable way in which the animal responds is by *moving*. Motion may take place by the general contraction of the whole mass of protoplasm, or special strands of it may be especially contractile. Often there are projections of the protoplasm beyond the cell wall (*cilia*) which are highly contractile, and these by their activity enable the cell to swim (Fig. 7, 6-9).

In such an organism as we have been describing we have the simplest living, active, food-using, sensitive, self-perpetuating machine known to us. We may infer that such an animal has its functions reduced to their lowest terms.

81. The Functions of the Complex Animals.—The higher animal starts in life as a single cell, similar to those spoken of in Section 80. Their earliest activities, there-

FIG. 8.—Types of tissue cells. 1, white (ameboid) blood cells; 2, red blood cells; 3, ovum; 4, sperm cells; 5, ciliate epithelium; 6, sensory epithelium (from retina of the eye); 7, flagellate (collared) epithelium; 8, a netting cell from Hydra; 9, a mucus glandular cell; 10, connective-tissue cells; 11, fat cells; 12, a bone cell; 13, an unstriate (plain) muscle cell; 14, a ganglion (nerve cell) with its branches.

Questions on the Figure.—Compare the cells in this figure with those of the preceding and notice the similarities of differentiation. By reference, discover the functions of these various types of cells and see in what ways their structure fits them for their work. What points about them are constant? What most variable?

fore, are similar to those of the one-celled animals. Owing, however, to cell-division and to the fact that the cells remain together when they divide, these bodies in

time come to be made up of millions of cells,—each cell of which finally does some part of the general work. Because of this division of work the cells come to look very different from the original cell and from each other—more varied indeed than are the single-celled animals in Fig. 7. Some of these cells, varied to do different kinds of work, may be seen in Fig. 8. The essential contents of these cells are still nothing but protoplasm and the substances which protoplasm builds up; but it is clear, from the different kinds of work that they do, that there are some real differences in the protoplasm.

It must be borne in mind that the cells in the complex animal must do their work *individually*, just as the simple cell did its work. It is their united work that makes the life of the organism.

Such groups of similar cells are known as *tissues*. Several kinds of tissue may be associated into *organs*; and these various complex organs divide up the work necessary to be done among themselves. In this way it is more perfectly done and a higher type of animal body is possible. We shall now examine some of the more important functions, and the organs by which they are performed, in the higher animals.

82. Metabolism or Nutrition; The Central Function.—Under this head we shall include all the processes directly connected with the use of food. It includes the taking of food into the stomach (*ingestion*); changing it in such a way as to get it from the stomach into the blood (*digestion*); carrying it to all parts of the body (*circulation*); taking it up from the blood by the protoplasm of the individual cells, and building it up into the cell substance (*assimilation*); the getting of oxygen from the air or

water (*respiration*); the burning (or *oxidation*) of the substances in the cells—whereby heat, motion, and other necessary forms of energy are secured; the getting rid of the waste materials that always result from this oxidation (*excretion*).

This seems a very complex process, and we have given technical names for the various steps of it; but they are all really parts of one function—the *preparation and use of food*. The organs may be discussed under the following heads: the *digestive*, the *respiratory*, the *circulatory*, and the *excretory* organs.

83. **The Digestive Tract.**—This is a cavity in the body into which solids and fluid foods may be taken, in order that they may be absorbed through the wall into the system; for food is not really *within* the body until it has passed through the wall of the digestive tract, and food cannot be used by the cells until it is capable of passing as a fluid through cell walls. Most commonly the digestive tract is similar to that of the grasshopper—a tube passing through the body, with two openings (Fig. 5); frequently, however, it is merely a “blind” sac, with only a mouth (Figs. 9 and 46). This tube is always lined with a complete layer of cells, whose duty it is to secrete juices for the changing of the food and to absorb the food from the tract.

In a general way the anterior part of the tube is intended to prepare the food for *absorption* (*digestion*), and the posterior part actually absorbs it, though some of each work is being done throughout the tract.

Digestion is of two kinds: *physical* and *chemical*. Physical digestion consists in the breaking up of the food into small bits as in chewing or dissolving; the chemical diges-

tion takes place by the action of the juices secreted by the gland cells in the wall of the tract. The physical digestion takes place chiefly in the mouth and stomach; the chemical in the stomach and intestines. Absorption takes place in the stomach and intestines, chiefly in the latter. Usually the surface of the intestine is much increased by folds and coils, so that greater absorption is secured.

FIG. 9.—*Stenostoma*. In this worm the digestive tract (*dt.*) is a blind sac. *st.*, point where the ectodermal mouth joins the entodermal gut; *c*, cilia; *g*, ganglion (brain); *g'*, a new brain, forming for the new worm that is being produced by fission; *o*, mouth; *o'*, mouth of new worm; *w*, excretory system.

Questions on the Figure.—Compare this digestive tract with those of Figs. 5 and 58. What does *proctodæum* mean? How much of this is proctodæum? How would food be handled by a tract like this? What would happen to it after digestion? Enumerate the evidences that this worm is dividing.

Glands are very common in connection with the intestine. These may be simple, with only one or a few cells, or they may become very much branched and enlarged. Illustrations of the latter kind may be seen in the liver or pancreas of man and the higher animals. Seek figures of these in the reference texts.

Figs. 9 and 63 will show some of the main regions

into which the digestive tract is differentiated. Compare both of these with the condition in the crayfish or locust. (Fig. 5).

84. Practical Exercises for Library.—Why do animals need a complex digestive tract any more than plants do? Enumerate the regions in the digestive tract of man (see Human Physiologies). What are the reasons for this complex differentiation? Why is the digestive tract so long in some animals? What could have served as a *cause* in bringing about the greater growth of the lining of the digestive tract into folds and elevations? What advantage has these folds to the animal? Is the digestive tract in the crayfish longer than the body itself? What provision does the crayfish have for physical digestion? For chemical?

85. The Respiratory Organs.—Closely connected with the need of food is the need of oxygen, which must be had by all protoplasm. Closely connected with the use of oxygen is the formation of CO_2 , which for the health of the body must be removed from the cell where it is formed and then from the body as a whole. The term respiration is applied to the whole process and consists of the following steps: (1) taking oxygen from the medium (air or water) into the body fluids; (2) carrying O to the system; (3) transfer of O from the body fluids to the cells; (4) union of O with certain materials in the protoplasm forming, among other waste products, CO_2 ; (5) transfer of CO_2 to the blood; (6) CO_2 carried to the respiratory organ; (7) CO_2 given up from the blood to the outside medium.

The oxygen may be absorbed and the carbon dioxide eliminated through any moist, thin-walled structure containing blood or other body fluid; but in order to do this rapidly enough for the needs of active animals there must be much of this surface freely exposed to the air or water. This surface is the respiratory organ.

The skin is the sole respiratory organ in some animals, as the earth worm; and it is always of considerable importance as an aid to respiration in most animals, particularly those that live in water.

There are two special types of respiratory organs: (1) those that extend outward from some part of the body wall—usually found in animals living in water. They

FIG. 10.

FIG. 10.—Diagram illustrating gills, or branchiæ (*br.*). *b.c.*, body cavity in which the body fluids circulate; *ex.*, external medium in which the oxygen is dissolved; *w*, body wall.

FIG. 11.

FIG. 11.—Diagram illustrating lungs or trachea (*l*); other letters as in Fig. 10.

Questions on Figures 10 and 11.—What is the medium in which the oxygen is found in each case? Show in what respects each organ (gill or lung) is better suited to its medium than to the other. How is the organ in each case related to the body wall? What is gained over the plan of taking the oxygen through the general body wall?

go under the general name of gills (sometimes *branchiæ*). The blood goes out into these pouches and is thus brought close to the water (Fig. 10, *br.*). (2) Ingrowths from the body wall (or some other wall) into which the O₂ passes. These are hidden in the interior of the body. Such are called lungs, tracheæ, etc. (Fig. 11, *l.*) The blood in this case is on the outside of the organ proper.

These organs only get the oxygen into the blood. It must then be carried by the circulation to the places where it is really used. The last step, which takes place in the protoplasm itself, is the real respiration.

The same organs that admit the oxygen allow the CO_2 to pass from the blood into the air or water. This is an economy of organs, for the outgo of CO_2 does not in any way interfere with the income of O.

86. **Practical Exercises for the Library.**—Why do we call the respiratory structures of the crayfish gills rather than lungs? Make a diagram showing the relation between the blood and the organ and the water in this case. Does the O used by water animals come from the H_2O itself? Could you devise an experiment to test this? Find what variety you can in the location of the respiratory organs in animals. Is there any *general* law which expresses their position? Describe all the organs in man that take any part in our respiration.

87. **The Circulatory Organs.**—Because both the food and the oxygen are taken in at special regions, and yet are needed by groups of cells far removed from these points, some device is necessary to carry the materials back and forth. It is clear that this work must be done by a *fluid*. These body fluids—*blood* and *lymph*—thus render a service to the body similar to that of railroads in a modern community. The larger and more complex the animal, the more necessary and the more difficult the circulation.

In order that the fluids may be circulated satisfactorily there must be a series of vessels making a complete circuit; somewhere along the route there must be portions of the vessels that can contract in much a way as to force the fluid onward (*hearts*); in order that the fluids shall travel in a somewhat definite direction there will

need to be *valves* to prevent or retard back-flow; finally the blood vessels must have very thin walls *in all those regions where they are to give up or take in elements (capillaries)*. The capillaries are functionally the important part of the system. The rest exists for them. They are

FIG. 12.—A scheme to represent circulation of the blood. The arrows indicate the course of the blood. *a*, arteries; *aur.*, auricle or receiving portion of the heart; *d*, digestive tract; *c.d.*, capillaries of the digestive tract; *c.r.*, capillaries of the respiratory organs; *c.s.*, capillaries of the system; *va.*, valves; *ve*, veins; *vt.*, ventricle.

Questions on the Figure.—What portions of the apparatus are *necessary* in order to secure circulation? In which regions is the real work of the blood done? Why are valves essential? What common work is done in the three sets of capillaries figured above? What special type of work is done in each of the three?

found in all regions of the system that must be nourished and relieved of waste; especially in the respiratory, digestive, and excretory systems. (Study Fig. 12.)

88. Blood.—For the purposes named, only the fluid portions of the blood are absolutely essential; but in most instances there are also living cells in the blood, known as blood cells or *corpuscles*. The blood cells may have as their function the better handling of the O, as in the

red blood corpuscles; or they may have a variety of special functions, as in the white cells of blood and lymph, which seem to secure the general health of the body by protecting it against infections from the outside.

89. **Exercises for the Library.**—What part do the pigments (red, for example) play in the work of the blood? What duties are the white corpuscles supposed to do? What are the evidences for this? Is the composition of blood the same in different parts of the circulation? Illustrate. Is there anything in the one-celled animals that at all corresponds to circulation? Restate just why it is a necessity in the larger and more complex animals? What is the difference between an artery and a vein? Describe briefly the complexity of circulation in the human body.

90. **Excretory Organs.**—After the food and oxygen have been carried by the blood to the tissues, they are there taken up by the cells and used by them in building up the material and in furnishing the energy of life. Here is the really vital process. When the oxygen unites with the carbon or the hydrogen of the complex materials in the cells, it breaks these materials down into simpler compounds, some at least of which are no longer of use to the cell—are indeed hurtful and must be eliminated. This elimination is called *excretion*. One of these waste products is carbon dioxide. We have seen that it is eliminated through the lungs and gills, where oxygen is taken in. Another type of waste, always present and more difficult to be rid of, contains nitrogen (*urea* and kindred compounds). Most animals have specialized organs by which these are excreted (Fig. 13). They always consist essentially of tubes connecting the tissues, or the body cavity, with the outside world. This connection may be direct, as in many worms (Fig. 13, *f*); or very indirect through the blood, as in vertebrates. The organs are known as *kidneys* in the vertebrates. The

elimination of indigestible substances from the digestive tract is not excretion, in the sense in which we are using the term. Why?

91. **The Skeletal System and its Functions.**—The cells of the body frequently excrete from themselves materials which are of no further use to the protoplasm, but which may come to serve some important function if deposited around or among the cells. The cell walls themselves

FIG. 13.—Diagram of an excretory organ (*nephridium*) of a segmented worm. *b*, blood vessels; *c*, coelom; *d*, duct of nephridium; *e*, external opening; *f*, funnel, opening into coelom; *gl*, glandular or secreting portion; *s*, septum; *w*, body wall; *w*, wall of gut.

Questions on the Figure.—Judging from the relation of the nephridium to the coelom, to the blood vessels, and to the outside world, what would seem a reasonable function for this organ? What do the septa accomplish?

may be of such substances. The intercellular substance among the cells (as the hard part of bone), and sheets of protective material on the surface of the body (as in the *cuticula* of the locust or the shell of the clam) are examples of this.

Such secretions serve a very important passive function in protecting the soft parts and in furnishing hard parts, or *skeletons*, for the attachment of muscles. In such external skeletons as that of the crayfish the same

material serves both of these ends. In the internal skeleton of the vertebrates it chiefly serves as a support and an attachment for the muscles which move the parts of the body.

92. **Practical Exercises for Library.**—Of what various substances are the hard parts of animals composed? Where do the animals get the minerals that enter into them? Study out some of the various ways in which animals arrange this hard material for protection; compare the snail, the clam, the crab, the turtle, and others. Do you find that the forms that develop a strong protective shell are as active, on the whole, as those which do not? Describe briefly the nature and the purposes of the human skeleton.

93. **Growth.**—Growth, as we have seen, is the natural outcome of the use of food and is one of the most valuable of organic powers, but there are no special organs or tissues of growth. Just as every cell must finally assimilate its own food and use its own oxygen, so every cell is its own unit of growth. Growth merely means an increase of volume—or rather of *mass*. There are three forms of growth common in all living objects: (1) growth by absorption of water—as a dry seed grows on being soaked; (2) by the formation of living protoplasm and the multiplication of cells; and (3) by the formation and deposit, in or among the cells, of substances which are not living matter, as starch, fats, bony materials, etc.

Growth does not continue indefinitely, either in the individual cell or in the whole body made up by the division of these cells; but in each complex animal the time comes when the cells no longer have the power of utilizing their income in such a way as to grow and multiply. The cells grow old. The growing old and the death of the complex individual are due to the fact that the individual cells tend to lose their powers. Yet individual cells may die without the whole animal ceasing to live, and the

individual cells may continue to live, for a time, after the death of the animal.

94. **Reproduction.**—In the light of the tendency of organisms to lose the powers of growth and division—resulting in what we call old age and death—organisms could

FIG. 14.—Direct cell division (*amæba*). A, active specimen with pseudopodia; B, becoming spherical, preliminary to division; C–E, stages in division. *ec*, clear outer protoplasm; *en*, granular inner protoplasm; *f*, food vacuole; *n*, nucleus; *ps*, pseudo-podium; *v*, pulsating vacuole.

Questions on the Figure.—Why is this appropriately called *direct division*? What structures are divided? Are the resulting halves exactly or merely roughly equal, apparently? Do you see any possible gain to the organism in dividing?

not have persisted and increased on the earth but for the power to form *new* and *young* individuals, whose cells are not old. This is called *reproduction*. Reproduction, then, must include two things: (1) it must produce *new individuals*; and (2), what is quite as important, the new individual must be *young* again; that is, it must not inherit the age which the parent had at the time of reproduction. All organisms have this power of producing new individ-

uals; and all organisms that grow old have the power of giving to their offspring a new start in the matter of growth and cell division.

Just as is true of the other functions, reproduction in

FIG. 15.—Diagram illustrating indirect cell division. For the appearance of a resting (undividing) nucleus see Fig. 2. A, coil stage, in which the most highly stained protoplasm (*chromatin*) takes the form of a thread (*cl*); B, a stage in which the coil has broken into numerous short loops (*chromosomes*, *c.*) scattered through the nucleus; C, aster stage in which the loops come to be arranged in the equator of the nucleus; D, diaster stage, in which each loop has split lengthwise, and the halves have moved apart and are collecting about the two poles of the nucleus; E, later stage in which the chromatin is more compact and a new cell wall is being formed between the nuclei; F, each daughter nucleus has gone into a coil stage, and the cell wall is complete. Each nucleus next passes into a resting stage before dividing again.

Questions on the Figure.—Does this type of nuclear division produce a more exact division of materials than the direct? In what respects? Compare this figure with more complete ones found in reference books. Enumerate the various happenings that occur between the stage of the resting mother nucleus and that of the two resting daughter nuclei.

the lower forms is the function of the whole living animal. There are no special organs; the protoplasm merely divides. See Figs. 14 and 15 for the way in which this division may come about.

Even higher up in the animal kingdom the power of

dividing into two animals is a rather common one. We see it in *Hydra* (Fig. 46, *A*) and even in the worms (Fig. 58, *z*¹). This is an expensive method of reproducing and makes a great drain on the parent animal.

In most of the higher animals the function of reproducing new individuals is localized in certain organs—*reproductive organs*. In such cases the essential tissues that are concerned are the *ovary* in the female (which produces the *ova*) and the *spermary* in the male (which produces the *sperm*). These cells (egg and sperm) actually start the new individual (Fig. 8, 3 and 4). These are the constant elements in the reproductive system; the other structures, which serve to bring these two kinds of cells together and to protect them during their development, vary widely in the different animals. (See also the next chapter.)

95. **Motion and the Muscular System.**—The most important tasks which animals must perform are securing food and escaping their enemies. Both imply motion. The power of motion we have seen to reside in protoplasm. The motions of all animals are derived from the power of protoplasm. In one-celled animals certain parts of the protoplasm often become especially contractile. They may extend outside the body of the cell, as vibratile *cilia* (Fig. 7, 6-10), or be within, as in the stalk of *Vorticella* (Fig. 39, *m*).

In the higher animals we find cells of both kinds. Ciliated cells are found, for example, in the lining of the *trachea* where the vibrating cilia help to free the surface of foreign particles (Fig. 8, 5). In muscle cells, on the contrary, the contractile elements are entirely within (Fig. 8, 13).

Locomotion in different animals differs very much in its efficiency. This may depend on the character and amount of the muscular tissue itself, or on the attachments of the muscles, or on the satisfactory adjustments of the hard parts which serve as levers on which the muscles act, or, finally, on the nature of the medium in which the organism habitually moves.

While most animals have both motion and locomotion, there are many attached forms which have only the power of extending or withdrawing certain parts. Even in such forms as these, however, the young usually have a period of free locomotion before settling down. This power is of value in scattering the species, and suggests that the remote ancestors of even the fixed forms were free-swimming.

96. **Practical Exercises for Library or Field.**—Make a study of the special manner of locomotion in a series of animals in different media—air, water, or solids. What variety are you familiar with in swimming organs? In flying organs? In burrowing organs? In organs for walking on solids? Do any animals have satisfactory locomotion without any apparent *special* organs of locomotion? How is it done?

97. **Sensation and Sensory Structures.**—We have seen that the simplest bit of protoplasm is sensitive. This means that certain changes in the outside conditions bring appreciable changes in the behavior of the protoplasm. Protoplasm is *irritable*. These external stimuli first act at the surface of the simple cell; but undoubtedly the results pass on inward until all the internal structure is changed in some degree, if we could only see it. In other words, the protoplasm has the power of *conducting* impulses from one part to another. A stimulus at one side may produce its visible results at the other side.

As organisms increase in the number of cells, and as these specialize in the various ways indicated in this chapter, they would lose this power of quick response to their conditions, unless there is also developed some specially sensitive conductors to bind the deeper with the outer cells, so that all may act more harmoniously.

FIG. 16.—Scheme showing the essential relations of the parts of a nervous system; 1, the sensory end organ (epithelial); 2, afferent nerves; 3, central nervous cells (ganglia); 4, efferent nerves, leading to 5, muscle, gland, etc.; g, ganglion cells; gl, gland; m, muscle fibre; s.e., sensory epithelium.

Questions on the Figure.—What seems to be the special function of each of the parts or elements in this scheme? Your reasons for your answer?

In a complex animal, there are five sets of structures which are commonly found to do this work of co-ordinating the parts of the organism to each other and to the outside world. These are shown in diagrammatic form in Fig. 16. They are: (1) the *end organs* of sense, whose business it is to be especially sensitive and to receive the various types of external stimuli, as light, sound, contacts, chemical changes, and the like; (2) *conductive tracts* (*afferent nerves*) which conduct an

impulse from (1) to (3) the *central nervous system* (*ganglion cells*) where the impulse is received and suitable responsive impulses are started; (4) *conductive* tracts (*efferent nerves*) which make the work of the central organ of value by carrying an impulse to (5) some kind of cell which *acts*, as a muscle, a gland, a light-producing organ, or an electric organ. Trace the connection of these in Fig. 16.

The nervous apparatus may be much more complex than is indicated here, but these parts are essential. The special development and the location of the parts are very different in the groups of animals, depending on the differentiation of the animal in structure and in habits and powers. As we ascend the scale of animals the very greatest improvement occurs in (1), (3), and (5). The sense organs become more varied, more localized, more highly specialized, and more perfect in adjustment; the central nervous system becomes more and more concentrated and more closely co-ordinated as well as more complex; and the responding organs become more perfectly adjusted to the kinds of work the organism needs to do.

98. The Organs of Special Sense.—In the lowest organisms the sensitiveness to the various external stimuli that can excite protoplasm into activity is diffused over the whole surface of the body. As we ascend the scale the tendency is for certain parts of the surface to become especially sensitive to certain kinds of stimuli and to lose their sensitiveness for the other kinds.

Some of the most primitive and diffuse kinds of sensitiveness are to light, to temperature, to the chemical condition of the medium, and to touch. Touch and

temperature are, in the highest animals, more or less diffuse skin senses. The chemical sense has become, in the highest animals, localized about the head and its appendages, often in the mouth. We know it as taste and smell. Sensitiveness to light is highly concentrated

FIG. 17.—Diagram of types of nervous end organs. From various sources. 1, a tactile bristle (insect); 2, pit-like organ with a sensory cell (*s*), olfactory (fly); 3, a complex taste bulb with sensory cells (mammal); 4, an otocyst, organ to give knowledge of the direction of the pull of gravity, and of vibrations (mollusk). *b*, protecting bristle; *h*, hair; *n*, nerves; *o*, otolith; *p*, sensory pit into which the sensory cell protrudes; *s*, sensory cells.

Questions on the Figure.—What evidence can you give that these are sensory organs? Discuss the difference in their mode of receiving their stimuli.

in organs known as eyes, usually confined to the head. Beside these there is, in many animals, a localized sense of hearing, and a kind of gravity (or equilibrium) sense possibly associated with hearing in its evolution.

99. **Practical Library Exercises on the Special Senses.**—Lack of space forbids an extended treatment of the senses here, but the student should refer to the larger texts for figures and discussion of these most important and interesting powers and organs of animals. See Fig. 17 for some simple end organs of sense.

Why are taste and smell spoken of as chemical senses? Where are they located in earthworms? Where in fishes? What are the essential differences between taste and smell? What other value beside recognizing food would these senses have? Is there any way to prove that the senses of touch and of temperature are not dependent on the same end organs in our own case? Are *otocysts* hearing organs or equilibrium organs? What evidences do you find in the literature? Would the power to recognize the pull of gravity or sounds be more important to the lower organisms? Why? What are the lowest organisms known to hear? Would the power to make definite noises be an evidence that a given species has the power of hearing sounds? Trace out the various steps in the development of the more complex kinds of eyes from the simpler types? What is the simplest light-perceiving organ? What are the chief differences between the "insect" eye and the "vertebrate" eye?

100. Summary.

1. The simplest animals perform all the necessary functions by means of protoplasm.

2. In the higher animals all the cells retain for themselves the power of using food, of growth, of oxidation, and of eliminating the waste products from itself. Certain special functions as circulation, motion, sensation, and the like may be turned over to certain special groups of cells.

3. Associations of cells of similar kinds are called tissues; associations of tissues to perform a more or less definite work are called organs.

4. The principal functions of animals and the organs or systems of organs doing the work may be classed as follows:

*Function.**System.*

(a) Metabolism.....	Nutritive (digestive, respiratory, circulatory, excretory).
(b) Support and protection.....	Skeletal and integumentary.
(c) Growth.....	(No special organs).
(d) Reproduction	Reproductive.
(e) Motion and locomotion.....	Muscular, in connection with skeletal.
(f) Sensation.....	Nervous.

5. Metabolism includes both building-up processes and tearing-down processes. The former add to the materials of the body and include digestion and assimilation. The latter include the oxidation that takes place in the cells, the display of motion or heat that comes from it, and the excretion of the waste materials.

6. The hard or skeletal parts are secreted by certain cells. This material may be external or internal. It is important in determining the arrangement and action of the soft and more active parts of the animal.

7. Growth and reproduction are the outcome of the nutritive work. Growth means the building up of the individual; reproduction means the forming of a new individual at the expense of the old. Whether in the one-celled animals or the higher ones, reproduction is always a *division of the parent*. If only one parent is necessary, we speak of reproduction as *non-sexual*. If cells from two parents are necessary, it is called *sexual*.

8. The nervous and muscular systems are closely bound together, both in structure and function. All muscles have nerves running to them. Sensation alone, without power to respond would be of no value to an animal. In a similar way, power to act without the ability to get impressions of the internal and external conditions would be meaningless. The action would be unguided.

9. The special sense organs, as the retina of the eye, the taste cells, the sensitive cells of the inner ear, and the like, are made up of protoplasm which has developed one form of sensitiveness at the expense of other kinds. Naturally the senses have arisen in adjustment to those external stimuli which are most powerful in their influence on life. We do not have sense organs giving knowledge of general external conditions that have no power to mold life. The more complex of these senses have, beside the sensory part, certain structures which intensify or otherwise modify the original stimulus. This is seen in the lens and iris, etc., of the eye.

101. Supplementary Topics for Themes in Zoology or English.—1. Why is the plan of dividing up the work to be done, among special organs, better than having the whole organism doing all the work, as in the one-celled animals? Are there any disadvantages in this division of labor?

2. Compare the ways in which animals known to you capture their food and prepare it for swallowing. Enumerate the special structures that different animals have to enable them to do this.

3. To what extent and in what ways may foods be stored in the animal body for future use? Compare with plants in this respect.

4. Why can gills not be used satisfactorily in the air, nor lungs by water-breathers?

5. The special advantages of having the hard parts of an animal on the outside rather than the inside. The disadvantages.

6. The problems which a moving animal has may be stated as follows: (1) support in the medium, against the pull of gravity; (2) the displacing the medium in

going forward; and (3) guiding the body in a given direction. Which of these gives the most trouble to the animal in each of the following conditions: moving through air, through water, on the surface of the ground, or in burrowing? Study some of the organs by which *each* of these things is accomplished in *each* of these conditions.

7. How much do animals differ in their rate of locomotion? On what do the differences depend?

8. What senses has a dog or a cat? How do you prove your conclusions?

9. Can you compare a color sensation with one of touch? Why? Can you compare an odour and a sound? Can you compare a taste and an odour? Can you compare a sensation of sweet and of bitter? Can you compare a high tone with a low one? warm with hot? different grades of sourness? What is the point in these questions?

10. The three functions of our eyes are : (1) light sensation, (2) color sensations, and (3) formation of images of objects. Do all the simpler eyes of lower organisms give all three of these classes of information? Which probably appears first? Evidences.

11. Discover, by reference to books of Physics, the simpler facts as to the absorption or *osmosis* of dissolved substances. At what points in the nutritive process of higher animals must this absorption take place?

102. **Technical Terms to be Defined.**—Metabolism; growth; sexual reproduction; non-sexual reproduction; cilia; organ; ingestion; digestion; assimilation; respiration; oxidation; excretion; absorption; osmosis; gland; gill; lung; trachea; lymph; heart; capillary; blood corpuscles; kidney; skeleton; cuticula; mass; ovary; ovum; sperm; sensory end organ; ganglion cell; afferent nerve; efferent nerve; otocyst.

CHAPTER X.

REPRODUCTION AND EARLY DEVELOPMENT.

103. **The Adult Individual.**—With sufficient nutrition and other suitable conditions of life, each individual comes to a natural maturity. In each species there are certain limits as to size and to length of life. There is, to be sure, some variation in these respects, but mice or horses or men do not pass beyond certain fairly well defined size and age. We do not know just what the cause of these limits is, but it is internal and not determined primarily by the outside conditions.

We think of the adult individuals of a species when we describe a species of animals. They are the normal members.

In most kinds of animals there are two kinds of adult individuals: males and females. These are often quite unlike in general appearance, in their special structure, and in their instincts and habits. Indeed, the males and females of one species are often more unlike than the same sex of two different species.

104. **Reproduction: Its Nature and Necessity.**—We have already seen (94) that some mode of reproduction is necessary in order to keep a species alive, since all the individuals grow old and die. Because individuals die, new individuals must in some way be formed; because individuals grow old and tend to lose their powers, the new individuals that are produced by the old must be restored

to the same sort of youth which the parent had at its beginning. The student must keep both of these facts in mind in all that is to be said of reproduction.

105. **The Formation of New Individuals.**—This is always done by some sort of division of the old individual. The parts may be equal or unequal; they may be just two or they may be numerous, but it is always a division at the expense of the parent, or original individual. It is just the opposite of the nutritive process. Nutrition builds

FIG. 18.—Diagram illustrating the reproduction of organisms by budding. A, yeast cells. *b*, the bud or daughter cell; *m*, the mother cell. B, *Chlamydomyxa*, a lowly protozoan. *c.w.*, cell wall; *n*, nuclear matter.

Questions on the Figure.—How does reproduction by budding differ from ordinary cell division? If the buds remain attached to the mother what is the result? If they become separate what results?

up, or increases the mass of the old self. Reproduction separates a new individual at the expense of the old self.

Practically all cells have, originally, this power of division or reproduction. We call it *cell division*. Some figures of its stages will be seen in Fig. 15. In this case the daughter cells are equal and there is no parent cell left.

Often, however, the daughter cell is not of the same size as the mother cell. It begins small and grows to its mature size (Fig. 18). This is known as *budding*.

Similarly, some animals, much more complex than these single-celled forms, show the same process of division or budding. Reference has already been made to *Hydra* and the worms (§94). This is a rather common process in the lower groups of animals. In such cases each of the offspring is a half or some large part of the whole animal, and has the power of producing a perfect new animal of the same kind.

It is not difficult to see that such a plan as this would be more and more difficult to carry out, as animals become more complex and highly organized. Because of this fact we could scarcely conceive of the grasshopper or the sparrow reproducing as the *Hydra* does in Fig. 46. Besides, it is a very expensive performance—a great drain on the parent; and nature is economical wherever she can be with advantage.

For the complex animals a more economical device has been found, thus: the adult, instead of putting aside as a daughter individual a large portion of its body, separates one or more single cells, each of which has the power, under favorable conditions, of developing into the adult of its species. All the possibilities of the parent are stored in this cell. By this device many offspring can be produced as economically as a few by the earlier methods. In this way provision is made for the high death rate among the young, because of their enemies and from other unfavorable conditions of life.

106. Males and Females in Reproduction.—The differences between adult males and females are continued into their reproductive cells. When females reproduce they do so by rather well-nourished, rounded, sluggish cells known as *ova* (Fig. 8, 3). Males reproduce by means

of small, highly motile cells, with little protoplasm outside the nucleus (Fig. 8, 4). These cells are known as *sperm*.

It is the case in many of the lower organisms that the same individual may be both male and female; that is, reproduce ova and sperm. Usually, in such cases, the two kinds of cells do not ripen at the same time, although they may do so.

FIG. 19.—A diagram illustrating the maturing of the male and female cells, and their union (fertilization) to form an embryo. A, the female cell (ovum); B, the male cells (sperm); C, the fertilized ovum or embryo. The numerals (1-5) indicate successive stages of maturity. *c*, chromosomes in the nucleus; *p.b.*, polar bodies; *s*, sperm cell.

Questions on the Figure.—What are the steps in maturing the ovum? What changes take place in the nucleus? Do the polar bodies have anything to do with the later development? Trace the steps in the formation of sperm from the sperm mother cells. What changes take place in the sperm nucleus? What are the differences between the nucleus of the fertilized ovum and that of the first stage,—A, 1?

107. Fertilization.—In producing ova and sperm the female and male individuals reproduce their kind; each kind of cell contains the qualities of the species. But ordinarily neither of these cells alone is capable of going on and dividing and making the growth that is necessary to form an adult. They do not behave like *young* cells. The full power of development comes only

when there has been a *union* of the two cells into one (Fig. 19, *c*). In this union there is a fusion of the male nucleus and the female nucleus into one nucleus, which occupies the protoplasm of the ovum. This result is called a *fertilized ovum* or an *embryo*.

This new organism, produced by the fusion of the two different kinds of cells, has a renewal of growth-power much greater than that possessed by either alone. It may develop muscle and bone and connective tissue and nerve cells. Fertilization has apparently made the egg-cell young again. It enters upon its youthful stages of development and has none of the age of the parent.

108. Other Modes of Renewal of Youth.—There are in nature certain other methods of renewing the youth of animals that have long been active. Such animals, usually unicellular or the lower sort of many-celled animals, may surround themselves with a thick wall and cease entirely from their activity. After a period of rest, the cyst may break and the protoplasm comes forth apparently with renewed power to multiply and grow.

In a good many animals, as plant-lice, bees, and others, it often happens that certain ova may develop without the union of the male cell. This is known as *parthenogenesis*. We do not know what gives them this power.

In recent years it has been shown that many kinds of eggs may be artificially fertilized by being placed in water containing materials in solution somewhat different from those to which the eggs are accustomed. This means that in some way this renewal of the youthful power of development is brought about by the stimulus applied from without—apparently chemical.

109. First Steps in Development.—The earliest stages in the development of the new individual after fertilization is the multiplication of its cells. One cell divides in two, these into four, and so on, until a large number of small cells is produced, which in the aggregate may be no larger than the original single cell. In this process some of the stored food of the ovum is used up in bringing about the divisions and in developing the new parts of all these cells, as nuclei, cell walls, etc. The daughter cells may be all of like size or there may be the greatest difference among them, but eggs of the same species always develop in much the same way. (See Fig. 20.)

110. The Conditions of Development.—The external conditions that favor development are, in general, those that are favorable to life itself, and it is unnecessary to enumerate them here. The internal conditions, those which the egg inherits from its parents and influence the way in which the fertilized egg develops, are enumerated below:

1. The size of the egg.
2. The amount of food substance stored in the egg.
3. The manner in which this food substance is distributed in the egg.
4. Whether the egg is encased in a hard shell.
5. Whether the egg is to be developed in the water or in a dry condition.

If the ovum is small and has little food, it will probably need to hatch and become active enough to secure its own food quickly. This is true of many water animals, as sponges, echinoderms, worms, etc. In the higher mammals there is little food in the egg, but the

FIG. 20.—A diagram illustrating the early steps (*cleavage and gastrulation*) which follow fertilization (Fig. 19, C). The vertical rows A, B, C, and D represent different kinds of fertilized ova. A, an ovum of little yolk; B, one with considerable yolk collected at the lower pole (*p.p.*); C, one with a large amount of dense yolk crowding the protoplasm to the upper pole (*a.p.*); D, ovum with dense yolk collected at the center. The numerals (1-4) indicate stages in cleavage and gastrulation: 1, fertilized ova; 2, the 4-8-celled stages of cleavage; 3, blastulas sectioned; 4, gastrula stage. *a*, archenteron, or primitive digestive tract; *a.p.*, active pole; *bl*, blastoderm; *bp*, blastopore; *ec*, ectoderm; *en*, entoderm; *p.p.*, passive pole; *s.c.*, segmentation cavity; *y*, yolk.

Questions on the Figure.—Why is one pole spoken of as active and the other passive? Which pole gives rise to ectoderm? Which to entoderm? Why does food substance interfere with the cleavage? What is the difference between segmentation cavity and archenteron? Note how the amount and arrangement of the food substance modify the archenteron.

developing embryo is retained in the body of the mother and nourished by her for a considerable length of time.

In eggs in which there is much food, as in the birds, the embryo develops on this food, and may get well on toward the adult condition before it breaks through the shell and becomes independent.

If there is little food, the early divisions produce cells nearly equal in size; if there is much food, these first daughter cells may be very unequal (Fig. 20). These inequalities have much to do with the later method of growth and differentiation.

III. Hatching and Birth.—Most eggs which develop outside the body of the mother are surrounded by a more or less definite membrane or shell for their protection. The early stages of division and change take place within this covering. When further growth demands that the young shall be free, this is burst and the embryo is said to *hatch*. The term *birth* is applied if the early development is within the body of the mother and describes the passage to the new life outside. The degree of maturity at birth or at hatching is not at all the same in different species.

II2. Direct and Indirect Development.—If the embryo hatches into the miniature of the adult, as in the chicken, the development is said to be direct. If, on the contrary, it hatches into some intermediate stage not having the adult appearance and organs, and later undergoes another change into the adult form, it is said to pass through a *metamorphosis*. This is true of the butterfly, the bee, and many of the insects, beside representatives of several

other groups of animals. (See Figs. 94 and 118.) The immature young is called a *larva*. Very often its habits and general mode and place of life is wholly different from that of the adult. For example, the larva of the mosquito is a water form and lives on the matter in stagnant water. The adult has a wholly different range of life and sucks the blood of higher animals as its food.

The change from the larva to the adult may be gradual (as from the tadpole to the frog) or may seem sudden because of the fact that the process takes place in a *cocoon* or something of the kind, with a distinct resting stage, as in the butterfly. This resting stage is called the *pupa*. The changes in the organs of the caterpillar are so profound that it could not adjust itself to an active life while they are being made.

The larval stage is usually one of voracious eating. During this time much fat is stored up for the change which is to come.

113. Practical Exercises for Library and Field.—Enumerate all the animals you are familiar with that undergo a metamorphosis. What are the chief differences in structure between the larva and adult? Illustrate the differences between their mode of life in the larval and the adult stages. What is the possible value of such an indirect development to an animal? What are its possible disadvantages? What is the special advantage of going into a pupa stage for the transformation from larva to adult, as compared with the way of the frog?

114. Specialization and Differentiation.—We have seen that the earliest stages of development consist largely of cell multiplication. The later stages may be said to consist of growth and differentiation. Sometimes there is differentiation during cell divisions as in those embryos where the first cells are unequal (Fig. 20, B, C).

But even when the cells are equal at the start, it soon comes about that the cells in the mass do not have the same relations to the outside world and are thus forced to be different. One such early difference is seen in Fig. 20, A 4, where the cells of one side have been punched into the interior. This condition is very common, and is known as a *gastrula*. In this there are two layers of cells, one on the outside and the other on the inside, and each comes to have its particular work.

Often the outside layer develops *cilia* and thus aids in motion and probably becomes more sensitive. The inside layer lines a cavity which may take in food. Its function then is wholly different: it becomes nutritive.

From these two layers, by cell division, by growth, and by gradual differentiation of certain regions of cells, we get all the organs of the adult animal of the species to which the egg belongs. It is not the purpose to trace this differentiation in the present book, but it is necessary to say that the organs that come from particular groups of these cells is not a matter of chance or uncertainty. We know not only that a frog's egg will produce a frog and that all frog eggs will develop in the same way, but also that the outside layer (*ectoderm*, Fig. 20, B, *ec*) will develop the outer surface of the skin and the nervous system, and that the inner layer (*entoderm*, Fig. 20, B, *en*) will finally line the stomach and intestines.

115. Practically all the many-celled animals start from a single cell and come to be some sort of a rounded mass of cells before they show much differentiation into organs. This means that the complex animals begin life practically as unicellular animals, such as the protozoa; but it means more than this. It also means that all

higher animals, in their development, come for a little way along a somewhat common course. It has been found that the nearer alike the animals are in the adult state, the longer their parallel development is. The individual starfish, the grasshopper, the crayfish, the frog, and man begin life quite similarly, as a single cell. The cells divide, and they all pass through a *morula*, or mass of undifferentiated cells, and later a *blastula* stage. Soon they begin to be different, but the grasshopper and the crayfish, being fundamentally more alike when adult, follow a similar course of development longer than the other types. The frog and man, being vertebrates, have stages in common which they do not share with the grasshopper. This increase of the differences continues until they reach the mature condition. The diagram, Fig. 160, will further illustrate this truth.

116. **Heredity.**—Why should a grasshopper and nothing else develop from a grasshopper egg? There are only two sets of influences that could act to bring it about: (1) the internal influences which come to the individual from the sperm cell and the ovum, and (2) the external influences. The first we call *heredity*, the second *environment*. Any quality or power which the individual gets directly from its parents *through the egg or sperm* is a hereditary quality; nothing else is. In some way each fertilized egg inherits the power to become a fish or a frog or a man, as the case may be. It may also inherit the power to become a certain kind of frog or man, even down to color of the eyes or personal tendencies.

The ovum and the sperm then are the connecting link between the individual and its past ancestors and are

the carriers of all the hereditary traits that may be transmitted. The protoplasts of these reproductive cells have crowded into them all the potencies of the bone and muscle and nerve cell; of all the organs described in the preceding chapter, and of all the instincts and powers of the mature member of the species. Heredity gives continuity to the successive generations of animals; makes it possible for us to speak of a species or race of animals.

It does not explain a quality to say that it is inherited, but it is often convenient to distinguish between characteristics that come directly from the parents and those that come through the environment.

117. Library Exercises.—Would the influence of the parent on the embryo *after* the union of ovum and sperm be a matter of heredity or of environment? Why? Do both the ovum and the sperm contribute to the hereditary qualities? Do they contribute equally in the long run? Evidences? Are differences between offspring due only to environment? Or might offspring *inherit* any of the differences which exist between them and their parents and among themselves? What is *atavism*?

118. Summary.

1. Adult individuals grow old and die, because the cells of which they are composed gradually lose their powers.

2. At certain stages of life individuals have the power to separate from themselves, in one way or another, single cells or groups of cells, which are young again and have the power of independent and separate life. This is reproduction, and makes possible the continuance and even increase of the species, in spite of death.

3. There are several methods which animals use to accomplish the result:

A. Not involving a union or *fertilization* (*non-sexual*).

Division into equal parts:

Two parts (cell division, Fig. 14; paramecium, some aquatic worms, Fig. 58).

Numerous parts (as in Sporozoa, Fig. 18).

Division into unequal parts; budding (as in Hydra, Fig. 46).

B. Involving a union of cells—*fertilization* (*sexual*).

Uniting cells much alike (some protozoa).

Uniting cells different (*ova* and *sperm*: most animals).

Male and female cells produced by the same individual—*hermaphroditism*. (Earthworm, tapeworm, many snails.)

Male and female cells produced by male and female individuals—*sexual dimorphism*. Most higher animals.

(In several groups both sexual and non-sexual methods of reproduction may exist side by side or may regularly alternate.)

4. Fertilization consists in the mingling of the contents of two specialized reproductive cells. The result is an embryo with the power of developing into the mature individual of the species.

5. The first step of development is cell division. The cells remain together and form a *morula* of undifferentiated cells. These cells arrange themselves into a two-layered sac (*gastrula*). The shape of the gastrula and the relations of these layers to each other and to the cavity, as well as the special mode of development, are determined by the amount and arrangement of the food in the egg.

6. The later steps consist of the development, from

these two layers, of the beginnings of all the special organs of the adult. This comes about through continued cell division, growth, and cell differentiation.

7. If the embryonic growth is steady and the organism hatches out with the organs and form of the adult the development is called direct. If the embryonic stage differs strikingly from the adult it is said to undergo a metamorphosis.

8. Animals begin life much alike and become gradually more different as they approach their mature condition. The more nearly alike they are in the adult the longer is their development parallel.

9. Every individual gets some of its qualities directly from the fertilized ovum; others it gets from the external conditions. The former are hereditary. The two great questions we are trying to answer about heredity are: What qualities are capable of being inherited? and, How are these qualities lodged in the ova and sperm?

119. Supplementary topics for themes in Zoology and English.

1. What are the distinctions between an *egg* and an *ovum*? Illustrate.

2. The maturation of the ovum. The steps in it and its supposed value and purpose.

3. What are the evidences that the cells of the body grow "old"?

4. Parthenogenesis in the animal kingdom. Its occurrence and possible value.

5. The real differences between budding and equal division.

6. Differences between the metamorphosis of the frog and that of the house-fly.

7. Alternation of generation. Where found. Its essential meaning. How does it differ from metamorphosis?

8. Differences in the eggs of animals—in size, shape, envelopes, amount of non-living food substance, etc. What classification of ova do the text-books make?

120. **Technical Terms to be Defined.**—Egg, ovum, fertilization, embryo, parthenogenesis, artificial fertilization, hatching, birth, metamorphosis, larva, pupa, morula, gastrula, ectoderm, entoderm, heredity, environment, hermaphroditism, sexual dimorphism.

CHAPTER XI.

THE LATER DIFFERENTIATION OF THE ANIMAL BODY.

121. **A Resume of the Early Stages.**—The new individual may be said to enter upon its life when the ovum is fertilized. The cell divides, and these daughters divide, and we have successively a 2, 4, 8, 16, 32-celled mass (*morula*, Fig. 20). The cell divisions continue, and by the time the food in the egg is used up the young animal must be far enough along to use food from the outside. This results in growth and further cell divisions. Sooner or later, by these means, a two-layered sac of cells (*gastrula*, Fig. 20, 4), is formed, made up of ectoderm and entoderm. These two layers of cells have very different fate in the later development of the individual.

122. **Mesoderm.**—In addition to these two primitive layers there is another mass of cells which comes to lie between the ectoderm and entoderm. It is somewhat less definite than the other layers and may be formed in several different ways. It is usually derived from the entoderm or the ectoderm or both. This mass of cells is known as *mesenchyme* or *mesoderm*. The mesoderm may entirely fill the cavity between ectoderm and entoderm, or it may split so as to contain a cavity completely surrounded by mesoderm. Such a cavity is known as the *coelom*, or *body cavity*. It will be seen from Fig. 21 that this cavity surrounds the digestive tract. Within it are developed and located most of the internal organs.

123. **Organs Derived from the Three Germinal Layers.**—From these three layers of cells all the organs of the body arise.

From the ectoderm come the outer layers of the skin together with its outgrowths, such as hair, feathers, and nails; the nervous system, including the brain and central nervous organs; and the sensitive cells, such as the retina of the eye, the taste cells, the epithelium of the inner ear, and the like.

The entoderm furnishes the lining of the digestive tract and of the glands that spring from it, including the lungs of vertebrates.

The mesoderm produces the muscles, the inner layers of the skin,

the internal skeleton of cartilage or bone, the connective or binding tissues, the blood and blood vessels, and the internal reproductive organs. In producing these organs two or more layers may be associated, as the ectoderm and mesoderm in forming the skin, or the entoderm and mesoderm in the digestive tract. In the latter the entoderm furnishes the lining which is digestive and absorptive; the mesoderm forms the connective tissue and the muscle fibres that cause contractions in it.

FIG. 21.—A diagram illustrating one of the modes of forming mesoderm from the entoderm of the gastrula. A, early stage; B, later stage. *a*, archenteron; *bp.*, blastopore; *cæ*, body cavity, formed from pockets of the archenteron; *ec*, ectoderm; *en*, entoderm; *m*, mesoderm; *m.so.*, mesoderm of the body wall; *m.sp.*, mesoderm of the viscera; *s.c.*, segmentation cavity.

Questions on the Figure.—What layer is most active in forming the mesoderm here? From what cavity is the cœlom produced? In what cavity does the mesoderm form? What finally becomes of the segmentation cavity? Compare figures in other texts and find in what other ways mesoderm is formed. Draw a diagram, by reference to other books, of a stage later than B.

124. Tissues.—In the differentiation referred to above the cells in the various parts of the body are becoming quite different from each other. In each of the complex organs there may be several kinds of cells that differ considerably in shape, size, and other respects. Groups of similar cells, differentiated from the other cells about them, are called *tissues*. It is well known that these groups of cells become especially fitted to do certain kinds of work:—some are specially sensitive; others are contractile; some manufacture and pour out secretions that influence the general condition of the body; and some produce hard and durable substances which furnish protection and support.

In this division of labor lies the advantage which the complex

body has over the single-celled animal with which we started. The necessary functions are performed in a more complete fashion, because of being given over to cells peculiarly fitted for their work. In gaining this fitness the cells lose the power to do other kinds of work.

In the development and differentiation of tissues—while the cell itself is the original element—it often comes about that the chief work of the cells is to secrete among themselves a substance (*intercellular substance*). After this is once produced, although it is dead and inert, it may become the important part of the tissue, as in bone or *dentine*.

In general it may be said that the cellular structure is the important thing in the active tissues. In passive tissue, however, the intercellular secretion may be the more important.

125. **Classification of Tissues.**—We may classify tissues in several ways. Perhaps the most meaningful classification for us is that based on their function. We may classify tissues as *passive* and *active*. The former are found in both plant and animals. The latter are confined to the animals. The active tissues are the *muscular* and *nervous* tissues. The passive tissues perform the *nutritive*, the *protective*, and the *supportive* functions. There are two main types of the passive tissues, the *epithelial* or bounding tissues, and the *connective* or supportive tissues.

126. **Epithelial tissues** (Fig. 22, *e*) always occur in layers, bounding and finishing the surfaces of organs and cavities. Such are the *epidermis* of the skin, the *mucous membrane* lining the mouth, the digestive tract and its glands, and the lungs; the *serous membrane*, which lines the body cavity and covers the outside of all the organs in it.

In addition to its finishing and bounding function, the epithelium may *secrete*, as in the glands; may *absorb* fluids and gases as in the intestines and lungs; may be *sensitive* as in the mucus membrane of the nose and tongue; may *produce new individuals* (ova and sperm), as in the reproductive glands.

In the gastrula the ectoderm and entoderm are epithelial tissues. At this stage the embryo is all epithelium. We may say, therefore, that it is the most primitive kind of tissue. Ectoderm, entoderm, and mesoderm all join in giving rise to the epithelial tissue of the adult. The cells of this kind of tissue usually retain their power of multiplication. This is the reason that new skin grows when the old is injured. This is not so true of any other kind of tissue. There is little or no intercellular substance in epithelial tissue.

127. Supportive or Connective Tissues.—These are among the most abundant tissues in the body and are correspondingly varied. They agree among themselves only in the facts that they originate from the mesoderm, are passive tissues, and tend to produce an abundance of intercellular substance.

After the cells once produce their intercellular substance, they themselves play a relatively unimportant rôle. It is the character of the intercellular substance that gives quality to the tissue. This substance may vary in consistency from fluid (as in blood) to the hardest organic substance known (as the enamel of the teeth); in

FIG. 22.—Gelatinous connective tissue bounded by epithelium. *c*, stellate connective-tissue cells; *e*, epithelium; *f*, intercellular fibres; *s*, gelatinous intercellular substance.

Questions on the Figure.—What seems to be the relation of the epithelial layer in this case to the tissue below it? What classes of cells are found in the gelatinous tissue? What is their origin? What is the origin and the nature of the intercellular substance? Are the fibres cellular or intercellular?

amount from almost nothing in its early embryonic form, to everything (as in dentine and enamel); in arrangement and structure, from a homogeneous matrix for the cells (as in some cartilages, Fig. 23, A) to pure fibres (as in ordinary connective tissue), or there may be a mixture of fibres and homogeneous substance, as in some cartilages (Fig. 23, B) and tendons. The intercellular substance may be wholly organic or very largely of inorganic salts, as in bone (Fig. 24).

The principal tissues that come under this head are gelatinous connective tissue (as in the mesoderm of the jelly-fish, Fig. 22);

fibrous connective tissue, which pervades the body of higher animals and binds together the muscles, the nerves, and other tissues; cartilaginous tissues, Fig. 23; tendons and ligaments; bone, Fig. 24; dentine, and enamel; and the nutritive fluids, as blood and lymph.

128. Practical Exercise for the Library (and Laboratory).—Demonstrations may be made of the chief types of tissue under the microscope, and the students allowed to examine them rapidly. Study

FIG. 23.—Cartilage. A, hyaline cartilage; B, fibrous cartilage. In the latter a large part of the intercellular substance is conspicuously fibrous. The cells occur in pockets (*p*) in the matrix; *f*, intercellular fibres.

Questions on the Figure.—What are the points of similarity and of difference in these two types of cartilage? In what way do the multicellular pockets arise? How do the unicellular pockets arise? What are the nature and origin of the intercellular substance in each case?

the various figures in this and other texts, and identify the cells and the intercellular substance. What of the amount and character of each? What are the exact functions of the various types mentioned in the preceding section?

129. Muscular tissue is one of the most distinctive tissues of animals. Its prime function is contraction. The simplest protoplasm is contractile in some degree, but muscle cells are peculiarly so. Furthermore, because of their elongated form their contraction takes place in one direction only, and hence a muscle contracts much more effectively than a simple cell. There is little intercellular

substance in muscle and the different fibres are bound together by connective tissue.

There are two main types of muscle cells found in the higher animals: (1) plain muscle (Fig. 8; 13), and (2) cross-striate muscle fibres (Fig. 25, *mf*). The latter are more highly organized and are more efficient and prompt in their action. In general, those muscles that are directly under the control of the brain, as the muscles that

FIG. 24.—Bony tissue, shown in cross section. *h*, Haversian canal, containing an artery (*a*) and a vein (*v*), lymphatic spaces, and nutritive cells; *c*, canaliculi; *l*, lacunæ; *la*, a plate of bony intercellular substance lying between rows of bone cells (*l*).

Questions on the Figure.—What is the difference between figures A and B? How does bone compare in appearance and in work with the other supportive tissues? How is its intercellular substance laid down? Of what is it composed? How are the cells in the bone nourished? How do they come to lie in the solid bone? What changes occur in this type of tissue with age? What is the function of the Haversian canals? Of the canaliculi?

move the skeleton, are of the cross-striate kind. Those which produce contraction in the stomach, intestines, and other organs not under control of the higher nerve centres are of the plain variety.

The fibres are bound together by connective tissue into bundles and these into larger bundles, and thus muscles are formed.

130. The Nervous Tissues.—Nervous tissues are closely related, on the one hand to the sensory epithelium of the skin and elsewhere, and on the other to the muscular tissue. Through the former they

receive the stimuli from the outside world (Fig. 8; 6 and 14); and they are able to produce response to these stimuli only because they are connected with muscles (Fig. 25, *n.m.*). Without the nervous tissue, the muscles' power of contracting could have no definite value to the animal; without the nerves and the muscle the sensitiveness of the end organs in the epithelium would amount to nothing. It really takes them all to furnish a complete function.

Nervous tissue consists of very complex and highly differentiated cells—probably the most highly specialized cells to be found in the body. The cells vary very greatly, but they agree essentially in the fact that the cell body (or *ganglion*) produces one or more outgrowths (or *fibres*) by which the ganglion is connected with other ganglia, or with muscles, or with sensory epithelium. The ganglion contains the nucleus of the cell and is the center of the activity of the entire cell. The fibres are merely outgrowths which conduct impulses to and from the ganglia.

The ganglion cells are massed together in nerve centres, such as the brain. The term ganglion is also applied to one of these groups of cells. When several fibres are bound together they are called a *nerve*.

The ganglion cell and its various fibres are to be looked upon as a unit. Fig. 25 shows the parts of such a unit. The whole nervous system of an animal is made up of numerous units of this type more or less joined together.

Nervous tissue arises in the embryo from the ectoderm. It is so highly specialized that its cells are probably incapable of division after they are once differentiated. This means that all the nervous cells are produced early in life, and that under ordinary circumstances no new ones are formed. Probably all we can do with them is to educate more highly those that we have.

131. **Organs.**—The tissues which have just been described are rarely, if ever, pure and independent; but are associated with one another in different ways. For example, connective tissue penetrates and binds together the nervous structures and the muscles. Nerves penetrate into tissues of all kinds. Covering almost all kinds of tissues we find epithelial cells. Whenever we have such a mixture of different tissues, bound together for a common work, as the heart or the stomach or the brain, we call it an *organ*. Organs may be associated into *systems of organs*, as the nervous system, the muscular system, the skeletal system. In such systems some type of tissue and function is predominant in importance. The other tissues present merely aid in this chief work.

FIG. 25.—Diagram of a nervous cell (*g*) in relation to a cross-striate (*voluntary*) muscle fibre (*mf.*). B and C show enlargements of a small portion of a fibre (*f*, fibril) of muscle; and D an enlargement of a nerve fibre, *n.f.* *a*, the axis of the nerve fibre; *g*, ganglion, or the central part of a nerve cell; *ax*, axon, or principal outgrowth of the nerve cell; *d*, dendron, or branched out-growths of the nerve cell; *n.m.*, the delicate plate of material where nerve and muscle unite.

Questions on the Figure.—Compare the striate muscle fibre at all points with the unstriate (Fig. 8; 13). How does the complex nerve cell differ from a typical cell? What are believed to be the special uses of the various parts of the nerve cell? Why is it necessary that nerve and muscle cells should be connected? What is a *neuron*?

FIG. 25.

132. The Changes that Come to Cells with Age.—The student should try to realize the great changes that have come to the cells of the body in passing from the fertilized ovum to such a condition as we find in one of the higher animals. All the living cells of the body, numerous, different, specialized, have come from the protoplasm of this first cell. (See Fig. 8.) Some of them, as muscle and nerve cells, are so changed that they have lost the power of division; some, as the red blood corpuscles, have degenerated to such an extent that they cannot repair the wastes and are continually dying out and being replaced by new ones; others, as bone cells, have secreted materials about themselves so that they are practically buried alive and depend on the nourishment that can percolate through minute passages in the bony matter; some, as the epithelial cells, have retained much of their power of division, as is shown by the way the skin is restored if cut. Yet all have a common origin in the ovum. On the whole, we are compelled to say that with all the division, growth, waste, and repair, and differentiation they have undergone, they show signs of loss of powers, and of old age.

133. Summary.

1. Divisions of the fertilized ovum produce first a mass of undifferentiated cells; the cells gradually become differentiated through inherited tendencies and from the result of the different positions in which they find themselves.

2. Groups of similar cells with similar powers are called tissues. In addition to the cells, there may be intercellular substance secreted among the cells.

3. Tissues may be classed either with respect to their structure or their activities.

A. Passive tissues.

I. Epithelial (cells in layers, little intercellular substance).
Kinds: pavement, columnar, ciliate, glandular, sensory, reproductive.

Functions: protection, absorption, secretion, sensation, reproduction.

II. Supportive or connective (usually much intercellular substance).

Kinds: gelatinous, fibrous, cartilaginous, bony.

Functions: binding, support, protection.

B. Active tissues.

III. Muscular (fibrous, little intercellular substance).

Kinds: plain, cross-striate fibres.

Functions: sensitiveness to nervous stimuli, contraction, motion.

IV. Nervous (branched and elongated).

Form: central cell (*ganglion*) with fibrous branches (*axon*, *dendron*).

Functions: reception of general stimuli, transmission of impulses, interpretation of these impulses, and starting responses.

4. Epithelial tissues arise from ectoderm, entoderm, and mesoderm; connective tissue from mesoderm; muscular tissue chiefly from mesoderm; nervous tissue from ectoderm.

134. **Supplementary Exercises for Themes.**—1. Differences between plant tissues and animal tissues.

2. The finer structure of the cross-striate muscular fibres.

3. How are nerves united with muscles?

4. Why would you expect nervous elements to arise from ectoderm? Why would you expect the nerve centres to sink below the surface into the deeper parts of the body?

5. Why are the epithelial cells the glandular cells?

6. What advantage is there in the fact that the epithelial cells retain considerable power of division?

7. What is there suggestive about the fact that it is epithelium which produces ova and sperm?

135. **Technical Term to be Defined.**—Mesoderm, cœlom, epithelium, connective tissue, intercellular substance, mucous membrane, serous membrane, tendon, ligament, dentine, enamel, ganglion, axon, dendron.

CHAPTER XII.

THE RELATION OF THE INDIVIDUAL TO ITS SURROUNDINGS.

136. **The Individual and the Environment.**—For several chapters we have been considering the single animal as an individual, in relation to its own parts, and these parts in relation to one another. It is now necessary that we return to the consideration of the individual in relation to its total environment. The student will find a use here for all his former observations in the field.

The forces within the animal, which come from its parents through the ovum and sperm and tend to guide and determine its development, we call hereditary. But this takes account of only one side of the question. The conditions of the outside—the environment—must equally be taken into account. Heredity determines that a frog's egg, if it develops at all, shall produce a frog; but the conditions outside largely determine whether the egg will develop at all, whether it will be well nourished or dwarfed, at what rate the development will proceed, and many other similar things. The conditions may be such as to prohibit entirely the development of the organism or they may merely modify it in various ways from what would normally be expected.

Some of the external conditions are so fundamental and powerful in their influence that all living things must become adjusted or adapted to them in some way in order to preserve their existence.

137. The Fundamental Conditions of Life.—Chief among the external conditions that influence life are food, oxygen, moisture, and suitable temperature. In the absence of any one of these, life, as we know it, would cease.

Not only are these conditions essential to life, but variations in them produce important changes in the living animals. The character of the food, the amount of moisture, the degree of heat and cold—all play their part in influencing the course of life in every individual.

138. The Secondary Conditions of Life.—In addition to the features mentioned in the preceding paragraph, there are other external influences that aid in molding the animal and its development, even though their influence may not be so profound as those mentioned. Among these are the pull of gravity, the chemical character and the density of the medium in which the animal lives, the atmospheric pressure, light (although not directly necessary to animal life is still a most powerful influence), electricity, and so forth. Many of the organs and instincts of animals are in adjustment to these conditions.

138a. Practical Exercise.—The student should illustrate from his own knowledge of animals some ways in which each of these factors of the environment can influence the life of the individual animal. What senses or powers or instincts are what they are because of these factors?

139. The Adaptation of Animals to their Environmental Conditions.—The most conspicuous fact about animals is that they are in greater or less degree adjusted or adapted in their structures and instincts and habits to the circumstances in which they live. They are not all adjusted in the same manner nor to the same degree.

Some are highly adjusted to light; others less so. Some are peculiarly adapted to high, and some to low, temperatures. Some are able to capture their food actively, others must take merely such as is brought by the currents in which they lie. There is thus a specialization in adjustment, just as there is in other respects.

Again, environmental conditions are continually changing. Food, temperature, moisture, and all the rest are variable. Animals must be able to adjust themselves not merely to the forces themselves, but to the changes as well, or they must be prepared to take the consequences. The changes may be daily or annual, may be irregular and sudden, or may be gradual and extending through long ages; but if there are changes in these real conditions of life, all animals must meet them in some way. When conditions change, the organism must either change sufficiently to suit them, or migrate and thus regain its accustomed conditions elsewhere, or die.

140. **A Classification of Adaptations.**—In a broad sense all the structures, powers, instincts, and habits which any animal has are adaptations to some external conditions which has power to influence its life. For example, the digestive tract is an adjustment—very varied in different organisms—to the existence and nature of food and to the services to which it may be put; the nervous system and the special senses are adjustments to light, to chemical conditions, to contacts, and other external stimuli; the lungs and gills are adaptations to the nature and need of oxygen; the organs of locomotion are adjusted to the pull of gravity and to the resistance of the medium in which the animal lives.

In addition to these fundamental adjustments there

are numerous special adjustments to the particular types of external conditions. For example, the eye of an organism that lives in water will differ somewhat from eyes used in the atmosphere; the stomach of a vegetable feeder will be constructed differently from that of a flesh eater; animals which use the air for locomotion must develop certain adjustments not found in those that walk upon solids.

The following outline of the principal classes of adaptations found in animals will aid the student in realizing how universal this principle is and how powerful the environment is in controlling the nature and form of organisms.

A. Adaptations to the fundamental conditions and activities of life. (The illustrations are not intended to be exhaustive; the student should find others.)

1. *To Food*.—The sense of taste and smell; hunger; the organs for capture of food, for digestion, absorption, etc.
2. *To Oxygen*.—Lungs, gills, skin, etc.
3. *To Moisture*.—Sense of thirst; power of absorption; coverings to prevent the evaporation of contained water; encystment and resting stages to resist drouth.
4. *To Temperature*.—Oxidation and animal heat; hair, fur, feathers; perspiration and its evaporation; hibernation, resting stages, winter eggs; migration.
5. *To Gravity*.—The sense of equilibrium; appendages; the supporting parts of the body.

6. *To Light*.—Eyes, and general light sensitive-ness; certain pigments.
7. *To the Medium*.—The skin and its special out-growths; sense of touch, taste, smell; organs of locomotion.

B. Adaptations to the special conditions of life.

I. Primarily inorganic relations.

II. Primarily organic relations (*i. e.*, adjustments to other organisms).

1. To animals of the same species.

a. Friendly and social.

Mating adaptations; parental care of young; organic colonies; social and communal life.

b. Competitive.

Struggle among members of the same species for food, mates, etc.

2. To animals of different species.

a. Friendly and social.

Commensalism; symbiosis.

b. Competitive.

The predaceous habit; adaptations for offense and defense; parasitism.

141. **Special Adaptations to the Inorganic Environment.**

—The great adjustments which all organisms must make to the non-living surroundings are suggested under "A" above. Under the present heading would come all the special degrees and variations of the qualities which give such variety and richness to animal life everywhere.

The adjustment to light is fundamental; but animals are very different in the way and degree to which they use it. Some animals love light and others shun it al-

together. Some have only pigment spots that give an impression of light, perhaps; others have such a perfection of eye structure that they see light and in addition distinguish colors, have from it a sense of direction, and get an image of external objects.

All animals are adapted to temperature in some degree; but some become so by an external covering of feathers, as the birds; others, as the whales, have a layer of fat beneath the skin which serves the same purpose. Many, by rapid oxidation, produce enough body heat to control their internal temperature; others do not, and are spoken of as cold-blooded.

142. **Practical Exercise.**—In a similar way, trace out some of the variations in the special manner and degree of adaptation to the various items under "A," found in animals of your acquaintance.

143. **Adaptations Among Animals of the Same Species.**—These relations are an interesting mixture of competition and co-operation. In many species the parents instinctively make great personal sacrifice that the offspring may be cared for; the offspring, on the other hand, contend with one another for this parental provision. In some instances the young actually devour one another. Each individual thus possesses both friendly and competitive habits and relations with the members of his own species.

144. **Mating Adaptations.**—One of the most striking series of adjustments found in animals are those which adapt the two sexes to each other. Indeed, the two cells which unite, and which represent the sex qualities, are themselves adapted in an interesting fashion. The male cell is poorly nourished and active; the female cell is well nourished and sluggish. They supplement each other,

and their union gives marvelous powers to the new cell, which neither had alone. In many egg cells there is the secretion of some substance which serves to guide the sperm toward the egg, through chemical sensitiveness. But for this adaptation fertilization would be much less sure.

In the second place, the structure of the males and females differs considerably and many of these structural differences make it more easy to bring the sperm and the ova together.

Finally, there are many habits and instincts of both males and females which help to insure mating and make it effective. The color of the male bird, his motions, and his peculiarly active song at mating time serve as recognition marks whereby his presence is made known to the female. In a similar way she has qualities that adjust her to the male. These mutual adjustments extend even to disposition.

145. Practical Exercises.—What is the difference in the notes of the male and female of the American quail which would serve as recognition marks? Mention other instances of differences between the sexes, which appear to you to adjust one sex to the other in such a way as to secure mating. What value is there in the mingling of sperm and ova? To what condition might the ability of ova to develop without sperm (*parthenogenesis*) be an adaptation?

146. Reproduction and Care of Young.—One of the interesting respects in which animals vary is in the rate of reproduction. Is there anything in the conditions of life to which this rate is an adaptation? Why does one animal produce only one young in a year and others produce thousands? Of course the present-day individual does so because it is the nature of the species; but how did the species originally come to have this nature

and to differ in this respect from others? Broadly, because the external conditions forced it upon them.

In general one pair of animals, no matter how many eggs are laid, will succeed, on the average, in bringing only one pair of their offspring to maturity during their own lifetime. The pressure of life is so great on the earth that, in the main, if one species increases in numbers it does so at the expense of others. This condition has been pictured as a *struggle for existence* among the animals of the earth. The great problem for parents is to bring two of their kind to maturity. This will keep the species up. This problem may be solved by producing many offspring—enough to sacrifice thousands with the chance that two may survive. Many animals adopt this plan (as the salmon and most insects). The more enemies the species has and the more unfavorable the general conditions, the more numerous must be the progeny. Thus the length of the reproductive life of the parents and the number of offspring are adaptations to the severity of the struggle for existence.

It is clear from these facts that any device which parents may adopt likely to bring the young more safely to maturity will make for a saving in the necessary birth rate. A little care of the young at critical stages saves the need of so many eggs. It will also save the parent a great physical drain and thus be an advantage to the species.

Parental care may take many forms. In its simplest form it consists of storing an extra amount of food in each egg, thus bringing the young to a better state of development when it begins to depend on its own efforts. Cephalopods, fishes, and birds have a large amount of food in the egg. Insects and many other types, instead of this,

place the eggs where outside food suitable for the developing animal will be abundant, as on leaves (Fig. 26), in fruits, in decaying meat, or other organic matter. After hatching, the care takes the form of protection or supplying food or both. Many animals, as the clam, some

FIG. 26.—Galls on hackberry leaf produced by a fly. Natural size. Photo by Folsom.

Questions on the Figure.—What does the gall represent from the point of view of the plant? From the point of view of the insect? What produces this abnormal vegetable growth? Find figures of other galls and compare. Find instances of galls in nature. In what ways might one determine what insect is responsible for a particular kind of gall?

fishes, some reptiles, and the mammals retain the eggs in special portions of the body until development has well begun.

An immense number of adaptations useful to the species have been developed in connection with the egg-laying habit. After such provision the majority of animals leave the young to take care of themselves; but many higher forms take further pains to protect and train the

offspring during the course of their development. The care which mammals and birds give to their young is a matter of common observation. It takes the form of special food; of homes—as nests, burrows, dens, etc.; and of the personal services of the parents who will often protect the young from its enemies, even at the risk of life.

This care of the young reaches its climax in man. The period of helplessness, during which the parents must care for the young, is longest in man. This period of helplessness tends to keep the parents together and furnishes the foundation of the home and the family life that has meant so much in human progress. These are the basis of human society; and, in turn, the progress of society and of its standards has made the care and education of the young more complete. In this way the character both of the parents and the offspring is improved.

147. **Practical Exercises.**—What habits or instincts have the following animals in the matter of caring for the young: flies; the solitary wasps; the ichneumon fly; social insects, as the bees and ants; the lobster? Add other instances of parental care that have fallen under your observation. What are “galls” on plants? How many different kinds can you find?

Compare the condition of the young of the robin, the quail, the blue-jay, and the pigeon, as to maturity at hatching. Do any animals of your acquaintance reproduce more than once in a year? Why is one reproductive period a year a common adaptation? To what is it an adaptation? Why do different animals have a different length of life? In general, how long will the life period be in a given species?

148. **Organic Colonies.**—In some of the lower groups of animals, as the polyps and sponges, in which the reproduction by fission or budding is prominent, the newly formed individuals remain for longer or shorter time in association with the parent or with one another (Fig. 27). They often secrete, in common, masses of material which

binds them into permanent *colonies*, as in the corals. Such colonies rarely occur among animals in which the organs are highly specialized. Colonial animals are almost always attached to fixed or to floating objects.

FIG. 27.—An organic colony of a fresh water polyzoan, *Plumatella*. After Allman.
stat, statoblasts, reproductive bodies.

Question on the Figure.—Evidences that this is a colony rather than an individual. Where are the younger and where the older individuals? How much constitutes an individual? What powers of adapting themselves to the surroundings do these individuals show? How are new individuals formed in the colony? How are new colonies formed?

Colonies are a successful device whereby limited areas are completely occupied by the combined offspring of one egg, where a single polyp would be well-nigh helpless.

149. Practical Exercises.—Study figures of colonies, in the reference books, and note their variety of form and size. What determines the shape which a colony takes? What phyla of the animal kingdom furnish instances of colonies? Are the individuals of a colony all alike? If not, what is the meaning of the differences? How are new colonies started?

150. Social and Communal Life.—Colonies are purely involuntary associations. Very often animals, not bound together, come into voluntary association. This may be temporary or fairly permanent. This social quality is seen in its simplest form as animals flock together to feed, merely because of abundance of the food preferred by the species. Similar to this are the shoals of fish that go to a common spawning ground. A step more intimate is the banding together of predaceous animals, as wolves or vultures, or pelicans, for mutual help in finding or taking the prey. Corresponding to this, on the part of the victims, we find the herding of bison, of deer and their kind for protection, whether by fighting together or by stationing sentinels who give notice to the feeding herd of the approach of danger.

A step more intimate still is the permanent union of thousands of individuals in the social life of such insects as ants and bees. This is usually associated with the instinct of home building and food storing, and thus a high degree of division of labor among the individuals of the colony becomes possible. In such cases the individual's life comes to be bound up in the success of the colony. Such forms usually give great care to their young, and develop a high order of social instinct and behavior. The principal social forms are the ants, of which there are more than two thousand species; some of the bees and wasps; the termites or "white ants"; beavers; some monkeys, and man.

151. Practical Exercises.—Make a report on the social life of the honey bee, including the following points: the home in natural conditions; the kinds of individuals in the hive, their origin, and their special work in the community; their food and its preparation; mode of caring for the young; swarming and its significance. Make a similar report concerning some species of ant. Give an account

of the social life of the beavers. What opportunities does social life offer for the care of the young? Find, by reference to texts, a series of forms among the bees intermediate between the solitary types and the social honey bees. How do the hornets pass through the winter?

152. **Competition Among Animals of the Same Species.**—

Animals of the same kind are not always in friendly relations, however. They use the same kind of food, and since thousands more are brought into life than can possibly succeed, there must sometimes be a very vigorous struggle among them for the food that is available for the species. Sometimes animals live directly at the expense of their own species. Young spiders are said to devour one another before escaping from the cocoon, which the mother has made for their protection. Many fish are known to devour their own young. Large frogs eat the small ones when other food is scarce.

One of the most striking forms of the competition between animals of the same sort is the struggle between the males for the possession of the females. It may take the form of actual combat, as in our barn-yard fowl or among the members of the deer family. Adaptations possessed by the males for this struggle are tusks, horns, spurs, manes, and even great strength and size as compared with the females. Of course these are not purely for such combat, for the same qualities which would make a male successful in his struggle with other males would be of value in the defense of himself and his mate, his young, and thus of the species, from their common enemies.

The competition between the males may be of a more quiet kind. It is believed by many naturalists that the striking colors, the song, the attractive behavior of males may have some part in determining the choice of

the female, in those species where monogamy prevails. The thought is that they displace their rivals not by strength, but by diplomacy.

153. The individuals of one species of animals may often be indifferent to the presence of another. Their relation is merely that of a kind of competition for food and air and water. They may graze in the same pasture, swim in the same pool, or even be parasitic on the same host, and have no other relation. Starting with this as the simplest relationship, we may pass by gradual stages to the most intimate friendships on the one hand and to the most bitter antagonism on the other. Probably to every species there are some other species that are friendly, some that are harmful, and some that do not directly influence it one way or the other. Man is no exception to this statement. There is no truth in the idea that all other animals were made for him and are of some use to him.

154. **Friendly Relations Among Different Species.**—Occasionally we find animals of different species forming a kind of partnership. An instance of this may be seen in the association of the prairie dog and a species of owl in the same burrow. There are hundreds of species of insects which live in the nests of ants. Each member of these associations can live without the other, but for some reason they usually occur together. This is known as *commensalism* or “*mess-mateism*.”

A somewhat more intimate relationship is found between the ants and the aphides or plant-lice. The ants capture the aphides and either nourish them outright or place them on plants of which the lice are fond, and in return the ants get the sweet secretion produced by the aphides. In

this instance there is believed to be a direct gain to both species by the association. Similar associations of crabs and sea anemones, crabs and mussels, are cited. This relation is called *symbiosis*.

FIG. 28.—*Argynnis cybele* on thistle. Natural size. Photo by Folsom.

Questions on the Figure.—For what purpose does the butter-fly visit the thistle? What special adaptations does the butter-fly possess for this mode of life? What is the gain to the thistle from the visits?

It is perhaps more common between plants and animals. In the case of the "ant-loving" plants it is believed that the ant protects the plant, in some instances at least, from other insects and that the plants secrete materials or furnish homes for the ants. Certain coelenterates have unicellular algæ imbedded in their own cells. These

algæ derive their nourishment from the waste matter of the animal tissues, and the animal cells profit by the oxygen and possibly other matter given off by the plants. Many of our flowers and our insects depend upon one another; the flower furnishes pollen and nectar as food to the insects; the insect helps to pollinate the flower and thus secures its fertility (Fig. 28).

The structures and instincts which make these various associations possible are adaptations to the existence of other organisms.

155. Competition Among Animals of Different Species and the Adaptations to it.—It is here that the competition in nature is most fierce, and its results are stamped upon the whole nature of the animal kingdom. It has been said that all species of animals have their enemies. There are two principal ways in which this antagonism may show itself: (1) in active preying upon other species or (2) in the underhand kind of preying which we call *parasitism*. The adaptations for the predaceous habit involve two kinds: the *protective* adaptations which enable animals to escape their enemies, and the *offensive* adaptations which enable the latter to capture their prey.

It is clear that in the long run there must be some balance between these two types of adaptations if both kinds of animals are to continue. If the offensive qualities were too well developed, it would result in the destruction of the prey which would mean also the end of the predatory forms. Similarly, if the defensive qualities outrun the offensive the captors would die out from lack of food.

156. Adaptations for Protection.—It is clear that keenness of scent, timidity which causes animals to keep in retired places, and fleetness, are qualities which will help

to preserve the life of the hunted. On the other hand, strength, bravery, and cunning are advantageous to hunters. In addition to fighting or fleeing, the animals which are preyed upon have many interesting devices that make for safety. Many forms, as the crayfish,

FIG. 29.—Nestling mourning doves (*Zenaidura macroura*). From U. S. Dept. Agriculture Year-Book, 1900.

Questions on the Figure.—Is there anything suggestive of protective markings? What are the mating and nesting habits of the dove? What character of nest is constructed? Are the young *precocial* or *altricial*?

have permanent outer coverings; most mollusks have a shell which serves as a box into which the animal may retire when threatened; others, by a burrowing habit or otherwise, may come to occupy obscure corners in nature where enemies find it hard to follow.

Hiding, while still leading an active life, is secured by

means of what is known as *protective resemblance*. Because of its form or color, or both, an animal may become much like its surroundings (Figs. 29, 30, 31), and thus escape observation. Sometimes this resemblance is to some particular object; sometimes merely a general harmony with the surroundings. Illustrative of the latter are the green caterpillars and tree-toads among the

FIG. 30.—Walking-stick insect (*Diapheromera veliei*) on twig. Natural size.
By J. W. Folsom.

Questions on the Figure.—To what group of insects does it belong? Do you see any reason to believe that it illustrates protective resemblance? Compare other figures in the reference texts.

green leaves; the quail among the dead leaves and grasses; the lizard on the lichened rock, the tawny color of desert animals, and the white fur of arctic forms. Most animals show some of this general likeness to surroundings, for it is advantageous both to the hunter and to the prey.

Many animals become inconspicuous by reason of resemblance to special objects. The walking-stick insects (Fig. 30) appears as a dead twig, when not in motion.

Many butterflies when resting resemble leaves. The body and wings of the katydid are green and the wings are veined somewhat like a leaf (Fig. 90). The larvæ of some of the moths, often called "measuring-worms," are remarkably like the twigs on which they crawl. When disturbed they often hold on by the posterior legs,

FIG. 31.—A sea-horse,—*Phyllopteryx eques*. From Eckstein.

Questions on the Figure.—Compare this figure of a sea-horse with figures of other species, and note the chief differences between them and the typical fishes. At what point does the tail of the fish end? What about the figure suggests protective resemblance?

and extend the body out in such a way as to make an angle with the twig, remaining in this position for many minutes. Similarly, devices for concealment are found among the fishes (see Fig. 31).

Other devices whereby animals protect themselves from their enemies are seen in the electric organs of some eels and other fish, in the poisonous fluids—with or without special stinging organs—as in coelenterates, bees, spiders, a few fishes, and some snakes; also in the repulsive odors of the skunk, the civet, and many caterpillars.

Caterpillars oftentimes have an acrid or unpleasant taste; but unless this is associated with a special odor or color by which its enemies may recognize the fact before they attack, it is not likely to prove of any great service to the animal possessing it, since a single break in its soft body made by the bill of a bird is likely to cause its death. For similar reasons animals with stings are often highly colored. The colors or other marks are, in these cases,

FIG. 32.—Protective mimicry of a drone bee (A), by a drone fly (B). (From Folsom's Entomology.)

Questions on the Figure.—Trace the points of similarity between these insects. By reference to text-books determine the usual differences between the flies and the bees.

in the nature of warnings; and the advantage comes from the warning quite as much as from the sting or the bad taste, because of the association of the two things in the memory of the enemies.

157. **Mimicry.**—These facts give rise to the remarkable phenomenon called *mimicry*. This term applies to those cases where an edible or harmless animal has a similarity of form or color to those that are dangerous or disagreeable (Fig. 32). It is believed by many students that such mimicking animals gain a distinct advantage from this similarity. It is necessary to remember that there is no

thought that this imitation is voluntary, but is simply the result of the better preservation of such animals as have in any way come to resemble harmful ones in that they are left more alone by their enemies. The "monarch" is one of our large conspicuous butterflies which has an offensive taste. The "viceroy" butterfly, though edible, has considerable likeness to the monarch in color-pattern, although its own nearest relatives are marked quite differently. It is thought that this may be a means of protection to the viceroy. Many flies and some moths and beetles mimic bees and wasps. Non-venomous snakes occasionally have the markings and motions of the venomous, although they may belong to quite different genera.

158. Practical Exercises.—Do you know by observation, of any wild animals that show a general protective resemblance? That show a special protective resemblance? What is the nature of the adaptation—form or color? Read all the references you can find on mimicry.

What range of color have you seen illustrated among animals? In a single animal? Where do we find the animals of brightest hue? What are believed to be the causes of color among animals? Enumerate the possible uses of color. What is albinism? Where is it found?

159. Adaptations for Attack.—Clearly, many of the qualities mentioned in the preceding sections as of advantage to the hunted will also be a help to the hunter. Often in finding their prey they need to be acute of sense, and in stalking and capturing it they need to be inconspicuous. In addition to these qualities there are others that are specially developed in the predaceous types. The sharp and pointed teeth, fangs, claws, talons; the cunning, stealthy mode of approach; the powerful final spring and general agility, are special adaptations to this mode of life. It is here that nature is "red in tooth and claw."

160. **Parasitism.**—Parasitism is an association of individuals of different species in which one member (the *parasite*) gets all the benefit and the other (the *host*) suffers the loss. Parasitism combines some of the qualities

FIG. 33.—Larvæ of bot-fly (*Gastrophilus equi*) in the stomach of the horse.
One-half natural size. From Luggar.

Questions on the Figure.—What can you find of the habits of the bot-fly? Where are the eggs deposited? How do the larvæ find their way into the stomach? How do they pass from this to the adult condition? How does the larva retain its position in the stomach of the host? What term would properly describe this kind of parasitism?

of commensalism and the preying habit. It is a kind of slow preying.

Parasites are of two kinds: *external*, as the fleas, lice, and the like; or *internal*, as most of the parasitic worms.

The fleas are *transient* parasites, as are many other insects which are free in the adult stage, but lay their eggs in or on the body of the host, where they undergo a partial development as parasites at the expense of the host (Figs. 33, 34). In other instances the parasite has come

FIG. 34.—A tomato worm bearing the cocoons of a parasitic insect. From Folsom's Entomology.

Questions on the Figure.—Seek for all possible figures of caterpillars attacked by parasites. Why would caterpillars be rather favorable hosts for insect parasites? Of what economic importance are these facts?

to spend its whole life in the body of one or more hosts. These are called permanent parasites.

It will be seen that the parasite increases the work to be done by the host, thus becoming a handicap in the struggle for existence. But since practically all animals support various parasites the race is evened up. It is to the advan-

tage of the parasite not to kill the host outright, especially if the parasite should be a permanent one. In transient parasites the life of the individual host is of no consequence after the end of the period of parasitism, and hence the entire destruction of the host's body may take place just as in the case of preying species.

Parasites are almost exclusively invertebrates. The worms and arthropods furnish the most numerous instances. Some of the Protozoa are internal parasites, sometimes being parasitic *within* the cells.

161. **The Adaptations of Parasites.**—Very profound modifications occur in the structure of parasites, which are the outcome of, and in part the adaptation to, their special and dependent mode of life. There is usually a degeneration of the organs of digestion, of motion, and of sensation, since the parasite depends on the host for the performance of these functions. The reasons why useless or unused organs degenerate are not fully known. It is known that lack of use causes an organ to deteriorate during the life of an individual; but whether this kind of deterioration can be passed directly on to the next generation is not known. Some naturalists claim that it may be; others, that it is not.

The reproductive organs become very complicated and the reproductive elements are produced in great abundance. This great reproductive power is an adaptation to the difficulties in finding the proper host. It is often the case that a part of the life is spent in one host and the rest in a host of an entirely different species. In order to insure that a single individual will get from one host into the other, many offspring must be produced. Most of them never succeed, and hence die.

Good illustrations of such parasites are the tape-worms (see page 189). There is a tape-worm which infests the trout of Yellowstone Lake. The larvæ enter the tissues of the trout and by their ravages weaken and kill the host. The dead fish are eaten by pelicans. The worms develop to the adult sexual condition in the digestive canal of the second host and the eggs or young embryos escape into the water with the excreta, and from there are taken up by other trout. Thus the infection spreads. It is clear that the passage from one host to another is helped, and possibly arose, through the carnivorous habits of some animals.

Parasitism is an adaptation to a very special mode of life in which the common nutritive difficulties are reduced to a minimum; the great activities of the parasite cluster about reproduction.

162. **Practical Exercises.**—Find other illustrations of parasites that must pass from one host to another. What are the means of accomplishing it? Is one of the hosts always carnivorous? Are there any vertebrates which are parasites? Enumerate the common parasites, transient and permanent, which are known to infest man, and find to what groups of animals they belong. Make a special report on the most common parasites of man, as tape-worm, trichina, etc. What other hosts are demanded to complete the life cycle? In what way can we prevent the entrance of these parasites into the human system? What is known of the cause of malaria? Of yellow fever? How are these parasites brought to man? Examine the mouth parts of the mosquito (Fig. 103). To what kind of feeding are they adapted? Would you call the mosquito a parasite? Make a study of the transient parasites? Are any other transient parasites responsible for the transmission of internal parasites dangerous to man or to the domestic animals?

163. **The Origin of Adaptations.**—One of the most interesting questions in the theory of biology is this: How have these adjustments, which we see between organisms

and their surroundings and between organs and the work they must do, come about?

There are several possible views:

1. The organisms may have been created in adjustment with the surroundings. In this event we have no way of discovering the real causes of the harmony. This has long been the view of most people.

2. Scientists believe, however, that the harmony and adaptation we see are the result of gradual growth, change, and development through the ages. The differences among evolutionists are as to how this development has come about. It is agreed that the changes which produce the adjustment are in the animals rather than in the surroundings, although the surroundings do change somewhat. It is further agreed that the surroundings have such a life-and-death influence over the animals that ultimately they must come into essential adjustment to the surroundings or die.

At this point evolutionists part company. One school thinks that the environment acts directly on an individual and forces it to change because of this action, and that this individual transmits some part of this change to the next generation; this new generation, if again acted on by this same environment, will change even more fully than its parent did, and thus, generation by generation, there will be an increasing harmony between the organism and the forces about it, through the inheritance in one generation of the acquirements of the preceding.

Another school does not believe that the changes which come to an individual in its lifetime, as the result of the direct action of the environment upon it, can be transmitted to the next, but rather that in the many variations which every family shows some variations will be more

suitable to the surroundings than others. Those that have inherited qualities that are more in accord with the needs of the organism will have an advantage over the others in the struggle for existence, and will be more likely to survive, have offspring, and transmit the qualities that made them successful. In this way nature merely weeds out the animals that do not become adjusted to the conditions. This is called *natural selection*.

It is quite possible that both of these views are true: that the surroundings do have the power to force variation in accordance with the needs of the animal; and that the environment may select those that are in best adjustment to itself, no matter how the qualities arise. One thing, however, is clear: the environment can, in the long run, force adjustment by selection, even if it cannot make an organism vary in the right direction. This is because it has a kind of final veto power over characteristics that are out of harmony with it.

164. Summary.

1. The environment influences the development of the individual quite as really as ancestors do.

2. Food, oxygen, moisture, and temperature are the factors in the surroundings which have the most immediate influence on life. Following these, gravity, light, and the chemical condition and density of the water and atmosphere are important to animals in many ways.

3. The harmony which we see between animals and their surroundings we call *adaptation*. The structure, organs, habits, instincts, which show the harmony are called *adaptations*. All important and useful possessions are adaptations to some real features of the environment, to some actual need of the organism. Animals cannot

become adapted to conditions in the environment which do not have power of influencing life.

4. It is believed that adaption between animals and their surroundings has been progressive; that is, that the adaptation is on the whole more exact and successful in the higher than in the lower animals.

5. Animals are adjusted to the environment because they must be. The environment may produce the necessary changes directly, or it may merely select those animals whose hereditary characteristics are most advantageous and eliminate those which are not suited to the conditions, or it may do both. In any event it is the environment which finally determines the adaptation.

165. Topics for themes in Zoology or English.

1. What is the difference between an individual and a colony? Is the "Portuguese man-of-war" an individual? Evidences?

2. Can you prove from your own observations that the use or disuse of an organ produces changes in it. Give illustrations.

3. Have you ever observed any changes in animals which were due to the action of the environment?

4. Can you illustrate what is meant by heredity by a series of facts of your own observation?

5. Are the offspring of the same parents alike? How much variety have you ever noticed? Did they inherit their differences or acquire them?

6. Does the mother have any more hereditary influence on the offspring than the male? Evidences.

7. Can offspring be *unlike* their parents through the influence of heredity?

8. Cite some instances of voluntary association which

you have observed among animals of the same species. What seems to be gained by the association?

9. What is meant by degeneration among animals? Under what circumstances do they degenerate. Cite instances from your reading.

10. In what respect are the higher animals better adapted to the environment than the lower ones?

11. Why is the leap or spring a good adaptation for capturing prey or escaping from enemies? Cite all the instances which you know from your own observation.

12. Discuss the value of the food-storing instinct. To what is it an adaptation? Cite instances, together with all the details you have observed.

13. Is there any definite relation between the instinct of home building and the degree of parental care? Use both observation and reading.

14. Study sleep among animals. What is its relation to rest? To what is sleep an adaptation? When does it commonly occur among animals? Why? Do plants show any sleeping qualities? What is the condition of the bodily activities during sleep?

15. Give instances of animals being brought gradually to endure conditions which would have killed them if employed suddenly. What explanation can be offered for this?

16. Define *habit*. Why does the repeating of actions tend to form habits? What is the value of this fact to man and other animals?

17. What do you understand by instinct? Look up at least three authors on the subject.

18. What gain is there to the child, in the human species, because of the long period of dependence on the

parents? What qualities does this condition tend to produce in the parents?

19. What is meant by "*mutation*"? In what way does it bear on the question of the origin of adaptation?

170. **Derive and Define the Following Terms.**—Adaptability; encystment; hibernation; commensalism; symbiosis; colony; community; society; mimicry; carnivorous.

CHAPTER XIII.

PHYLUM I: PROTOZOA.

171. General Survey of the Group.—These are the minutest of the animals and cannot be studied in the laboratory without the compound microscope. The following facts make them of special interest:

1. While they are very small, they are perfect cells and have all the powers necessary for successful life. They take food and digest and assimilate it so that it builds up the body; they move and change their form; they are sensitive; and they reproduce. So perfect are these powers that they increase very rapidly, if the food and other conditions are favorable, so that the water literally swarms with them. If conditions become unfavorable, they as quickly disappear.

2. They are found in any waters on the earth where life is possible at all; though they are most abundant in stagnant waters where there is much decaying matter. They are able to use matter so fine and so nearly decayed that it would not be used by higher animals. They, in turn, become food for animals somewhat higher up. In this way they prevent much organic matter becoming inorganic and useless to other animals.

3. Some of them live as parasites in the bodies of other animals. They are so small that they may live within the cells. The parasite which produces malaria lives and multiplies in the human red blood corpuscles. Other human diseases are due to parasitic protozoa.

4. Many of these single-celled animals are so like the single-celled plants that no sharp line can be drawn between them.

5. Many of them have the remarkable power of drying up, if the water fails, and of resuming activity when it returns. This enables them to be blown about as dust and thus to be scattered over the earth.

172. **The Ameba.**—This animal is common enough, but it is not always easy to find when wanted. It is most likely to be found at the surface of ooze in ponds or in vessels containing mud and decaying organic matter in the laboratory. It appears and disappears in a very puzzling way.

It is a clear, jelly-like object and is liable to be overlooked even when on the slide.

The ameba is one of the simplest of these simple animals. It is a single mass of protoplasm without a cell wall (Figs. 35 and 36). It is therefore very free to move. It will be seen to send out rounded or pointed (according to the species) projections or temporary "feet," in the direction in which it is moving. The inner and more granular protoplasm (*endoplasm*) streams out into this foot which at first consists largely of the clearer outer protoplasm (*ectoplasm*). In the meantime the protoplasm at the opposite side of the body is being withdrawn and the result is a slow motion in the direction of this growing "foot" (*pseudopodium*, Fig. 35).

When the ameba comes in contact with a small organic particle, such as it is accustomed to use as food, the protoplasm flows in such a way as to engulf it in the body. It does not enclose about a grain of sand. Thus it is seen to have some power of recognizing and choosing its food.

Within the endoplasm may be seen three different classes of objects: (1) granules and food masses of different sizes, sometimes inclosed in clearer circular spaces (*food vacuoles*); (2) a rounded nucleus; and (3) a clear, rounded object that contracts and expands (*pulsating vacuole*). It is not always easy to see the last two objects.

After growth to certain limits, the ameba divides into two practically equal parts (Fig. 14). The nucleus and vacuole divide and one half goes to each of the new cells so that there are two perfect small-sized individuals as the result. This is the usual mode of reproduction, and is as simple as can well be conceived.

Under certain conditions the ameba cannot continue this active

life. If the changes come slowly enough, it becomes round, draws in its pseudopodia, forms a protecting wall, and lies quiet until the return of favorable conditions.

173. Paramecium: A Laboratory Exercise.—This animal is especially favorable for laboratory work on account of the ease with which it may be had. Put some grass and some green matter from one or two ponds into a vessel holding half a gallon or more, and allow the materials to decay. Watch the surface of the water and examine under the microscope every few days.

FIG. 35.

FIG. 36.

FIG. 35.—*Amœba* in active condition. *ec*, ectosarc; *en*, endosarc, containing food vacuoles (*f*); *n*, nucleus; *p*, pseudopodium; *p.v.*, pulsating vacuole.

FIG. 36.—*Amœba* in the encysted or resting stage.

Questions on Figures 35 and 36.—Define the various terms used above in describing the *amœba*. What changes may the *amœba* undergo in its life-history? Why is it thought of as an especially simple cell?

Activities.—Run a little water, into which finely powdered carmine has been put, under the slide, and watch every activity.

Describe and figure every kind of movement of which you find them capable. Can you distinguish an anterior from a posterior end? Do you have any reason to believe the paramecia are sensitive to external conditions? What evidences. To what sorts of influences do they respond? Do they avoid objects? Do they tend to collect? Where? What might be the causes of this? Which seems to you most probable? Are they as active at the end of the hour as at the beginning? Can you find the organs of locomotion? Evidences?

Are any of the carmine particles inside the animals? Where? How do they get in? Do they move after they get in? Evidences. Have you seen any evidences of division?

Structure.—What is the general form of the body? Can it change its form? Does it come back to its original form? Why? Is there a wall? Is the body symmetrical? Show your ideas by a longitudinal view and by three imaginary cross sections taken at different parts of the body. If time allows, study the cilia, find the oral groove and mouth, identify the food vacuoles in the endoplasm, find the two contractile vacuoles and describe their mode of acting, and look for the nuclei (this requires a stained specimen).

FIG. 37.—*Actinomma*, a rhizopod with a shell and no mouth. A, whole animal, with a portion of two spheres (*sk*) of shell removed. B, a section. *n*, nucleus; *p*, protoplasm; *o*, openings through which the pseudopodia extend. After Parker and Haswell.

Questions on the Figure.—Compare these forms with the other protozoa figured and enumerate the points of likeness and difference.

174. **Vorticella.**—This beautiful animal (Fig. 39) is found under the same conditions as the *Paramecium*, and has much the same food habits and internal structure. It has the power of forming a contractile stalk by which it attaches itself to objects, and can when disturbed draw itself suddenly close to its support by means of a contractile fiber in the stalk. Its cilia are usually confined to the free end where the mouth is located. The animals may break loose from their attachment and swim freely in the water. Some species

are colonial; that is, they do not separate when they divide, but each daughter develops a stalk and remains attached to the main stem (Fig. 39, B).

175. *Euglena*.—This form is found under much the same conditions as ameba. Occasionally it is seen in great numbers making a thin scum on ponds, in very warm weather a short time after a rain. It is remarkable in that it has the green coloring matter of plants

FIG. 38.—*Paramecium* in optical section (semi-diagrammatic). A, anterior end; c, cilia; ec, ectosarc; en, endosarc; f.v., food "vacuole"; g, gullet; N, meganucleus; n, micronucleus; o, groove leading to mouth; p.v., pulsating vacuoles in different stages of contraction; v, a food vacuole in process of formation.

Questions on the Figure.—How do the anterior and posterior ends differ? Compare with other protozoa in this respect. What is there to convince one that this is a single-celled animal? Is it more or less highly "organized" than the other protozoa of which you can find figures? To what division of Protozoa does *Paramecium* belong?

and the motile condition of animals (Fig. 40, A). It differs from the ameba in that it has a wall, and has a single long lash (*flagellum*) extending from the mouth, which is a permanent opening in the cell wall. The flagellum enables the animal to lash its way through the water; it also aids in carrying food back to the mouth. There is a large rounded nucleus, and a peculiar red spot ("eye-spot") just back of the mouth.

176. **The Spore-animals.**—We usually think of plants alone as producing spores, but there is one group of the Protozoa whose

FIG. 39.

FIG. 40.

FIG. 39.—A, *Vorticella*, a stalked, ciliate infusorian:—1, contracted; 2, extended. f, food vacuoles; g, gullet; m, contractile (muscular) fibre; n, nucleus; o, mouth, surrounded by a ciliated disc; p.v., pulsating vacuole; s, stalk. B, a colonial type similar to *Vorticella*.

FIG. 40.—A, *Euglena viridis*, a flagellate infusorian. 1, typical swimming condition; 2, somewhat contracted; 3, spherical resting condition; 4, encysted stage in which division has taken place. c, cyst; f, flagellum; n, nucleus; o, mouth; p.v., pulsating vacuole, sp, pigment spot. B, *Podophrya*, a stalked infusorian bearing sucking tentacles (t). p, infusorian captured for food; s, stalk.

Questions on Figures 39 and 40.—Compare the internal structure of *Vorticella*, *Paramecium*, and *Euglena*. What are the principal similarities and differences? Compare all the protozoa figured, as to degree and method of locomotion, method of taking food, and mode of reproduction. Compare these types with those figured in Fig. 7.

cells divide into many of these rounded bodies (*spores*) when they reproduce. These animals are all parasites on other animals, and are usually even simpler in structure than the types we have been studying. Their life history (as is the case with most parasites) is quite complex. They often pass through a number of stages—some active in which they move about in the body fluids of the host, some encysted in which they divide rapidly and produce many spores, which become motile again and attack new cells.

In the case of the parasite which produces malaria in man (*Plasmodium malariae*), it works its way into the red cells of the blood. Here it multiplies and at the same time manufactures certain poisons which produce fever in the host. These new spores escape into the

FIG. 41.—Diagram showing the resting position of the body of the *Anopheles*, or malaria-carrying mosquito (A); and of *Culex*, another common mosquito (B). Adapted from Waterhouse.

blood, enter new red cells, until very great and dangerous infection may take place. If a mosquito "bites" a person with malaria, some of these cells are drawn up into the stomach of the mosquito. In the mosquito two of the cells unite or conjugate, and after some changes get into the salivary glands of the animal and from this point they pass to the blood of another human victim when this mosquito again seeks its food. (See Fig. 7, 5.)

A similar protozoan, also carried by a species of mosquito, is responsible for the disease known as yellow fever. A number of diseases of animals are produced by these sporozoa. They are therefore very important to man. The discovery of their work is very recent. The knowledge of the part that mosquitoes play in

distributing the parasites has changed our whole treatment of sanitation as it relates to these diseases.

177. Comparison of Protozoa: a Practical Exercise.—Let the student examine samples of all the stagnant waters in the laboratory. Look along the sides of the vessels, in the ooze at the bottom, on the sticks and algæ. Find all the different kinds of Protozoa that you can. Compare them with the descriptions and with figures, and see which of the types they most resemble. In what respects do all the kinds agree? In what particulars do they most differ? In how many different ways do you find them moving? How do the smallest and the largest compare in size? What have you seen as to their foods?

Study the figures and descriptions in the larger text-books, and find to what extent the form and size of the nucleus differ in Protozoa. In how many different ways do you find Protozoa reproducing? What kinds of Protozoa form shells? What do they lose and what gain by having the shells?

178. Definition of the Protozoa.—The Protozoa, then, are animals made up of one cell or of several similar cells loosely joined together (*colony*). The chief method of reproduction is by the division of the animal into two. Each of these may grow to the original size and divide again. In many cases two individuals may unite (*conjugate*), after a long series of divisions. This seems in some way to renew the powers of the protoplasm in such a way that the divisions may then take place more actively again.

179. Classification of the Protozoa.

Internal parasites; almost no organs of locomotion... Sporozoa.

Examples: Plasmodium malariae; Gregarina.

Free forms; protoplasmic appendages or processes.

Appendages temporary (that is, retractile)..... Rhizopoda.

No shell: Ameba (many species). (Fig. 35.)

With shells: Radiolaria; Foraminifera, etc. (Fig. 37.)

Appendages permanent.

One or few—and large (flagellum)..... Flagellata

Examples: Euglena, Eudorina, Volvox. (Fig. 40.)

Several or many, and small Infusoria.

Cilia. Ciliata.

Examples: Paramecium; Vorticella; Stentor (Figs. 38 and 39).

Sucking tentacles Suctoria.

Example: Podophrya (Fig. 40).

180. Topics for themes in Zoology or English.

1. The economic importance of Protozoa.
2. The diseases in man caused by sporozoa. The rôle of the mosquito in the life history of the sporozoa causing malaria and yellow fever. The bearing of these facts upon the management necessary to prevent the spread of these diseases.
3. Of what substance is chalk. How is it produced?
4. Why should Volvox and Euglena be considered animals rather than plants?
5. Conjugation in Paramecium: its method and its results. What part do the nuclei play in the process?
6. Conjugation in Vorticella. How does it differ from that of Paramecium?
7. Variations in Protozoa as to the size, shape, and structure of the cell.

CHAPTER XIV.

PHYLUM II: PORIFERA.

181. **General Survey.**—All sponges live in water. All except one family live in the ocean. They are found in all parts of the oceans, but those species whose skeleton we use as a bath sponge are found most abundantly in the Mediterranean and Red Seas and in the Indian Ocean. This is the only respect in which sponges are of value to mankind. Several species are found along our own shores in relatively shallow water, and these with the fresh-water sponge are the forms most usually studied in the laboratories of the country. The group is not a very large or important one. It is interesting to zoologists chiefly because of the following facts:

1. It is the lowest group in which the animals are made up of three layers of cells. In some respects they are intermediate between the protozoa and the higher animals.

2. They are attached like plants in their adult stage (see Figs. 44 and 45), and they bud and branch in a non-sexual way, so that the descendants of one individual come to cover much space as a single colony. But it is to be remembered that they start life as a single cell and in the early stages the animal is ciliated and free-swimming, much like the Protozoa. It is the lowest group of animals to pass through the stages mentioned in 121.

3. Instead of having one mouth, as all the higher animals do, the sponge has numerous small mouths ("pores") through which the currents of water carry minute parti-

cles of food. Apparently the food is not digested in this general cavity of the animal, but is taken up by the individual cells and digested in the cells, much as in the case of the *Paramecium* and other Protozoa.

182. A Simple Sponge—*Grantia*: a Practical Exercise.—This small cylindrical sponge is found on our own coasts, at slight depths. It occurs in clusters, attached to various kinds of objects. While it is not the simplest type of sponge, it is good to give a general idea of the structure of sponges. Specimens may be preserved in alcohol. Some should be allowed to dry for comparison.

After studying the general shape and size of the body, and any differences that can be seen between the two ends, and the arrangement of the pores and spicules as they appear from the outside, split the body longitudinally with a sharp scalpel. Examine these hemisections carefully, within and without, with a hand lens and identify and describe the following:

The general body wall: its thickness and character. Is it solid or perforated? Notice the shape or the cavity (*cloaca*). Does the cavity have any communications with the outside world? Do you find any signs of the pores on the inside?

With a razor, make some cross sections just as thin as you can, and study these with the low power of the microscope. Study the pores and the canals and the spicules, and see if you can make a diagram to show your idea of the conditions. How does the food get into the animal?

183. The Sponge of Commerce.—This bath sponge is merely the horny skeleton of a large ocean sponge which is much more complex than *Grantia*. This skeleton is developed in a similar way to that of *Grantia* and corresponds to it, though it is a much more perfect skeleton. The soft, living parts have been destroyed in the process of preparing the sponge for market. Just as in *Grantia*, the skeleton was developed in the middle layer of cells (*mesoderm*) and there was on the outside a layer known as *ectoderm*. Lining the interior of the canals and cloaca was the *entoderm*.

184. The Essential Structure of Sponges.—It will be seen, from the two examples that have been described, that while the sponge is much more complex than the Protozoa, it is very much simpler than the ordinary animals. There is no heart, no brain, no lungs, no organs for locomotion or for special sense. The body consists merely of a body wall surrounding the cloacal cavity (Fig. 42), lined with

entoderm. Tubes lined with entoderm pass out from this central cavity through, or into, the body wall. These tubes may enlarge into chambers (Fig. 42, *ch*) also lined with entoderm. Into the outer part of these chambers tubes lined with ectoderm enters. It is through these passages that the water, bearing food and oxygen,

FIG. 42.—Diagram of a simple type of sponge. *c*, cloaca; *ch*, chambers, lined with flagellate entoderm; *e.p.*, external pores; *i.p.*, internal pores; *mes*, mesenchyma; *o*, osculum; *r.c.*, radiating canals.

Questions on the Figure.—What portions of the animal are lined with entoderm? With ectoderm? What two main types of entoderm are figured? What is the actual character of the mesoderm in sponges? Is there a coelom (*i. e.*, a cavity bounded by mesoderm)? Why is it better for the water to pass in through the pores and out through the osculum, rather than the other way? Compare with Fig. 43. Fig. 42 is merely a later stage of Fig. 43, 5. What changes have taken place?

enters the animal. The united currents, bearing the wastes of the body, pass out through the larger opening (*osculum*; Fig. 42, *o*).

The body wall is composed (1) of the outer layer of cells (*ectoderm*), the inner layer of cells (*entoderm*), and (3) between these a gelatinous secretion in which there are several kinds of cells (*mesoderm*; Fig. 42, *mes*). There are cells in the mesoderm which secrete the skeleton;

there are others which move about, like white blood corpuscles, and may have something to do with nutrition; there are at certain seasons still others that form eggs and sperm. These unite, in fertilization, to form an embryo and finally a new mature sponge.

The entoderm cells, lining the passages, are supplied with flagella, the lashing of which produces the inward currents of water which are so essential to the life of the sponge. These flagellated cells apparently have the power of capturing particles of food in somewhat the way *Euglena* takes its food.

FIG. 43.—Diagram to illustrate the development of such a sponge as Fig. 42. 1-5 progressive stages from egg to gastrula, ready to become fixed. *a*, archenteron; *bl*, blastopore; *ec*, ectoderm; *en*, entoderm; *mes*, beginnings of mesoderm; *s*, segmentation cavity.

Questions on the Figure.—Is cleavage equal or unequal in this egg? How does the manner of forming mesoderm compare with that in Fig. 21? What changes take place between stage 5 in this figure and the condition in Fig. 42?

185. Reproduction and Development of the Sponge.—It has been seen that the great masses of sponge, representing a large colony of individuals, may be derived from one egg by a kind of budding or non-sexual reproduction. These non-sexual buds may or may not separate from the parent. There is also the reproduction by eggs and sperm. These are produced by the same parent. The sperm

is motile and the fertilization takes place in the mesoderm. After development has proceeded a little way the young mass of cells escapes and becomes free-swimming. It forms a *gastrula* (see 114 and Fig. 43), settles down and becomes attached by the end that contains the opening (Fig. 43, 5), and gradually assumes the adult condition (Fig. 42). The sponge may be looked upon, then, as a modified gastrula, even in its adult condition.

FIG. 44.—*Leucandra*, a simple type of sponge. From Delage and Herouard.

Questions on the Figure.—Which is the attached and which the free end of this sponge? Where is the osculum? How many individuals are shown in the cut?

186. The Conditions of Life in the Sponges.—Sponges are very much influenced by their surroundings. No two are ever the same shape. They conform to the shape of the object on which they are fastened. Individuals of the same species differ greatly as they may happen to grow in fresh and active currents or in sluggish water, on rock or on muddy bottoms. The different species differ all the way from forms which settle on rocks and

gradually dissolve passages in the material and build their living cells along these passages to large erect individuals a foot or more in height and supported by well-developed skeletons.

The sponges have interesting life relations to many other forms. While they have no power of attacking animals other than microscopic ones and few or no animals use the sponges directly as food, their thicket-like masses furnish a hiding place for many species of minute worms, crustacea, and the young of many species. They are protected from attack on the part of the higher animals by the toughness of the skeleton and probably by unpleasant odor and taste.

187. Definition of the Porifera.—The Porifera are to be distinguished by the following facts:

1. They are multicellular in the adult, and are made up of three different layers of cells—ectoderm, entoderm, mesoderm.
2. They have numerous openings by means of which water, bearing their microscopic particles of food, is swept in by the action of ciliated cells.
3. They are wholly aquatic.
4. Sponges develop a skeleton in the middle layer which supports the body and furnishes a framework that determines the shape the animal will have.

188. Classification of Sponges.—The classification is based on the character of the skeleton, and on the nature of the entodermal canals in the body wall.

Sponges with calcareous or limy skeleton.....Calcarea.

Example: Grantia.

Sponges not having calcareous skeleton.....Non-calcarea.

Siliceous skeleton. *Examples:* Fresh-water sponge, "Venus Flower Basket."

Horny skeleton. *Examples:* The bath sponges.

189. Topics for Themes in Zoology and English.—

1. Economic value of sponges. Sponge fisheries and the manner in which they are conducted. Sponge "farming"

off the coast of Florida and its methods. The mode of preparing sponges for the markets.

2. What arguments can be advanced for thinking of the sponges as colonial Protozoa? What is conclusive for regarding them as really Metazoa?

FIG. 45.—*Axinella polypoides*, showing numerous oscula. After Schmidt.

Questions on the Figure.—What are the principal external differences between *Axinella* and *Leucandra* (Fig. 44)? How many individuals are represented here? What are your grounds for your answer? Compare this with the skeleton of the sponge of commerce.

3. The skeleton in sponges. Beside the differences in material, in what different ways are these materials built up in order to make a skeleton?

4. What is the advantage in having the water pass in

through the small and out through the large opening, rather than the reverse?

5. By reference to various text-books, give an account of the different degrees of development of the canals and chambers in the walls. Which is the more active in their formation, ectoderm or entoderm? Possible reasons for this?

CHAPTER XV.

PHYLUM III: CŒLENTERATA.

190. **General Survey.**—This branch of animals is found almost wholly in salt water. There is one small group of them (the *Hydras*) that live wholly in fresh water and a small number of examples that live in brackish water or, if in fresh water, quite near the seashore. This suggests that these latter types are just now gradually making a transition from salt to fresh water.

This is one of the most beautiful and varied of the lower branches of animals. It includes the jelly-fishes, the sea anemones, the corals, and the sea-fans. Many of these are very delicate and beautifully colored; and they often occur with great luxuriance on rocky bottoms of the warmer seas, unless too deep. Here they look like gardens of many colored plants. With the exception of the jelly-fishes and a few others, they are like the sponges in being attached, in forming great colonies by budding, and in secreting supporting skeletons. They differ from them in being more branched, in having waving tentacles, and in great diversity of color. The branching habit gives them an added likeness to plants. In addition, the group is especially interesting to the student because of the following facts:

1. The body, especially in the region of the tentacles, is covered with minute nettling cells (Fig. 46, *n*) with which they paralyze their prey and perhaps protect themselves.

2. These are the lowest animals in which we find well developed nervous and muscular cells which play an important part in all the higher animals.

3. There is only one opening into the digestive tract (see *m*, Fig. 46).

4. In many of them there is a beautifully exact radial arrangement of the parts of each individual around a central point. This is seen to best advantage in the jelly-fishes.

191. The Fresh-water Hydra: a Laboratory Study.—This is the simplest of the coelenterates, and yet it gives a good idea of the essential structure. They are common in ponds and lakes and brooks where the water is not too foul, but they are easily overlooked. The best way to secure them is to bring in leaves, submerged plants, algæ, and the like from a number of places. Put them in separate glass dishes and label them so that you will be able to locate them again if you succeed. Do not allow too much decay to take place in the material. Watch carefully on the sides of the vessels and on the leaves for the extended hydras. There are two common types—a smaller green hydra and a brown species. The green are more hardy, but the brown are more satisfactory for study. Study alive in a glass jar or tumbler.

Is it free or attached? General form and regions of the body? Tentacles, number and position. Enumerate the activities that you discover. What degree of change of form is possible to it? Under what circumstances does it change form? Is it moving at all when undisturbed? Watch for some time. What is its customary position in the water? Is it heavier or lighter than water? Does it ever become detached? What evidences?

Devise experiments to test the following questions:

Is it sensitive to touch? Equally sensitive in all parts of its body and tentacles? Evidences. Has it anything corresponding to a sense of taste? Evidences. Can you get it to take food? Try it with one of the small water fleas often found in aquaria, or with a piece of meat not larger than a small pin-head. Place against the tip of a tentacle. Note every motion of the tentacle and of the body. Can the Hydra swallow? Try similarly with a small piece of paper. Compare its behavior in the two cases. Are hydras sensitive to light?

Classify all the results you have, under the heads: motion, locomotion, nutrition, sensation. Are there any other questions you would like to ask? Can you devise some way to answer them?

Transfer the living animal to a watch-glass containing a little water and examine with the low power of your microscope. Draw carefully the outlines of the animal extended and contracted. What differences can you see between the attached end and the free end? Has the animal any sort of symmetry? What regions and structures of the animal seem to you to need names? Is there any internal cavity? If so, where is it? Are the tentacles solid structures? Evidences. Are there any buds on any of the specimens? If so, draw several in different stages.

From mounted and stained microtome sections the teacher may at least demonstrate the general arrangement of the ectoderm and endoderm layers in the various parts of the body.

The netting cells may be studied, unexploded and exploded, with the high power, by transferring the animal to a slide and covering with a cover-glass. A small drop of dilute acetic acid added to the water will cause many of them to explode. Compare with figures.

If it is impossible to get living specimens the general structure of

Hydra may be studied by comparing the figures to be found in several text-books. (See Fig. 46.)

FIG. 46.—A, a longitudinal section through the body of Hydra (diagrammatic). B, small portion of the wall, more highly magnified. *b*, bud; *ect*, ectoderm; *ent*, entoderm; *f*, foot; *fl*, flagellum; *g.v.*, gastro-vascular cavity; *m*, mouth; *mes*, mesenchyma (non-cellular); *m.f.*, muscular processes of the ectodermal cells; *n*, netting cells; *n'*, same, exploded; *nu.*, nucleus; *t*, tentacle; *v*, vacuole.

Questions on the Figure.—How many layers of cells are to be made out in the wall of Hydra? In what way does the ectoderm of different regions vary? The entoderm? What is the relation of the bud to the mother? Why is the cavity called a “gastro-vascular” cavity? How is contraction effected in Hydra? What difference of function can you suggest for ectoderm and entoderm?

192. **The Hydrozoa: Polyp stage.**—The group of cœlenterates includes, beside *Hydra*, many similar forms which are considerably more complex. They are like *Hydra* in that they have only one cavity in the body in which digestion and circulation take place. The mouth opens directly into this. There are only two layers of cells, the ectoderm and entoderm, but between these is a layer of secreted substance which helps to give form to the body. Like *Hydra*, they bud, but the new individuals remain attached to the old

FIG. 47.—*Hydractina echinata*, after Hincks. *c*, canosarc, forming an incrustation over the object on which it lives. From this the polyps bud. *n*, nutritive polyps; *r*, reproductive polyps, bearing buds in which are ova; *t*, tentacles.

Questions on the Figure.—How many types of individuals seem to be represented? What evidence of reproduction by budding? How does this colony compare with that in Fig. 48?

in such a way as to produce colonies of these slender tentacled individuals (Fig. 47). The colonies are attached. While containing many animals these colonies do not become very large. The ectoderm has the power of secreting a layer of horny matter which forms the skeleton of the main stalk and branches, and protects the soft parts. As is seen in the buds of *Hydra* (Fig. 46, *b*), the digestive cavity is continuous between the bud and the mother. This brings

FIG. 48.—A very diagrammatic illustration of a complex coelenterate colony. The shaded portion represents the gastro-vascular cavity; the light portion the body tissues. *b*, a bell-like individual developed into an air bladder; *m*, mouth; *n.z.*, nutritive individual; *p.z.*, protective individual; *r.z.*¹⁻³, different types of reproductive individuals; *s.b.*, swimming bell; *t*, tentacles, which are sensory and protective structures. After Lang.

Questions on the Figure.—What shows that this is a colony rather than a complex individual? In what respects is it similar to an individual? What is the function of the gastro-vascular system? How do the Siphonophora differ from the other colonial coelenterates?

it about that every polyp in the colony is connected with the digestive cavity of every other, and there is a possibility of co-operative nutrition not often found in colonies.

In some of these simpler colonies all the budded individuals are much alike; but in some of the complex ones the buds may become different and do different work for the colony. Some may capture

FIG. 49.—*Physalia*, the Portuguese man-of-war. After Agassiz.

Questions on the Figure.—For what is this animal remarkable? To what group of cœlenterates does it belong? Compare Huxley's figure of the same animal (see Parker and Haswell's *Zoology*, Vol. I, p. 152, and other reference texts). What various types of polyps are represented in the colony? Compare this condition with the diagram in Fig. 48.

food, others may swallow and digest it, and still others may become reproductive bodies by which new colonies are formed. (See Figs. 48, 49.) This is seen in its most extreme form in the Portuguese Man-of-war (Fig. 49). This degree of differentiation of individuals could not come about but for the fact that all may get food from the common digestive tract.

The life of the polyps goes on much as in *Hydra*, the growth and budding continuing in a purely non-sexual way. But, unlike *Hydra*,

FIG. 50.—Diagrams of jelly-fish. A, viewed from the oral surface; B, a section through the center of the animal and along the line $a-a'$ in A. The shaded portion is the gastro-vascular cavity, lined with entoderm. The outer boundary is ectoderm and the unshaded part is mesoderm. $o-ab.o.$, oral aboral axis; $a-a'$, $b-b'$, radial subordinate axes.

Questions on the Figure.—Work out the details of the symmetry here. What does it mean to say that the animal is radially symmetrical? By comparing the two figures and other figures in the reference texts, trace the course and division of the gastro-vascular cavity. Identify the mouth, the gullet, the radial canals, the circular canal, tentacles, the sexual bodies.

many of these polyps have no power of producing eggs and sperm. Under certain conditions, however, they produce buds very different in appearance and internal structure from the usual polyps. They are shorter and more fleshy (Fig. 48, *b*). These are known as *medusæ* or *bells*.

193. Medusa Stage.—These new buds do not bud when mature, as their parents did, but break loose and become free-swimming animals. They have a sort of bell or umbrella form, with the mouth

in the center of the concave side (Fig. 50). Around the extreme margin is a fringe of tentacles. The bell can contract in such a way as to force out the contained water and thus swim along slowly through the water. There is still only the single cavity lined with entoderm (*gastro-vascular*), but it is more complex and branched than in the polyp stage. All the parts are arranged with the most precise radial symmetry. (Fig. 50.)

When mature the medusa produces eggs or sperm or both, and after fertilization the embryos develop, much as described in Section 114. They are free-swimming for a while and then settle down and become attached. As this embryo develops, it forms not a medusa like its parent, but a polyp like its grandparent. The medusa is a delicate and fragile organism, and probably its individual life is quite short. They are in this respect similar to some of the insects that live only a few days after their metamorphosis into the adult stage—just long enough to reproduce satisfactorily.

194. Alternation of Generation.—The process that has just been described—polyps reproducing non-sexually by budding and forming medusæ, which reproduce sexually and form polyps—is known as *alternation of generation*. The polyp stage enables the descendants of one egg to become very thick over a small territory, by budding. The free medusa, scattering its eggs, enables the species to take possession of new territory. While the medusa dies after a period of reproducing, the colony of polyps does not, unless overcome by a disaster of some kind.

While the alternation of generation is common in the Hydrozoa, it is not universal. There are polyps that have no bell stage and there are bells that have no polyp stage.

195. The Large or True Jelly-fishes (Scyphozoa): A Library Exercise.—Examine the descriptions and figures in a number of advanced texts and compare with the conditions in the smaller jelly-fishes or medusæ of the Hydrozoa.

What are the difference as to the development and position of the tentacles? Differences in the radial canals of the gastro-vascular cavity? Is there a fixed stage? How does it differ from the tubular polyps of the Hydrozoa? What is the nature of the non-sexual reproduction? Is this an alternation of generation?

196. The Sea Anemones.—These are barrel-shaped organisms that grow singly and attached to the rocks in shallow waters near shore. They have great numbers of tentacles, and often present vivid colors. They sometimes grow to great size, reaching one to one

and one-half feet in diameter. Most species, however, are much smaller, ranging from one-fourth inch to two or three inches.

The mouth is in the middle of the free end of the animal. When food is taken into the mouth it does not pass at once into the gastro-vascular cavity. It enters an œsophagus or gullet lined with ectoderm (Fig. 51). This gullet opens below into a central cavity which

FIG. 51.—Diagram of sea-anemone. A, cross section; B, longitudinal section. Lettering as in Fig. 50. *c*, chamber between the mesenteries (*m*).

Questions on the Figure.—How does the symmetry of this animal compare with that of the jelly-fish? Compare these with figures in reference books showing the whole animal. Trace the extent and divisions of the gastro-vascular cavity. Identify mouth, gullet, tentacles, mesenteries (primary and secondary), ectoderm, entoderm, and mesoderm. What is there about the structure of this animal that seems to adjust it to its mode of life?

extends outward to the body wall. It is partially divided up, however, by a series of flat radial partitions (Figs. 51, *mes.*), some of which run from the body wall to the gullet. The whole cavity is lined with entoderm. Food may pass out into any of these chambers between the partitions, from the central cavity just below the gullet.

The mesenteries bear masses of nettling cells and the reproductive bodies. The eggs or young finally escape through the mouth to the outside world.

Sea anemones may also bud, as in *Hydra*, or divide longitudinally into daughters of equal size.

Anemones are well supplied with muscular fibres, both longitudinal and circular, although they have no power of locomotion. When low tide leaves them bare or when disturbed, they have the power of contracting their muscles in such a way as to withdraw all the tentacles and to close up the whole free oral surface. In such a contracted position they have nothing of the beauty which they show when extended.

197. **The Corals and Sea-fans.**—Closely akin to the anemones, both in form and in internal structure, are the corals. They differ in the fact that the corals develop a supporting skeleton of limy (corals proper) or horny (sea-fans) substance, and in the fact that they are usually colonial while the anemones are solitary. The colonies are formed by budding, as in the *Hydrozoa*, but in the corals much more of the hard material is deposited, and great masses of carbonate of lime (limestone) are formed. The coral reefs and coral islands found in the tropical seas are the products of these small polyps.

Coral masses differ very much in form. Some are slender and branching, as in the sea-fans and tree corals; others are spherical and massive, as the brain corals; still others are flat. If budding and secretion take place in all directions, and the different polyps grow at much the same rate, a form like the brain coral will result. What conditions of budding and growth would produce forms like the branching or tree corals? See figures in various text-books.

198. **Ctenophora or "Comb-jelly": a Library Exercise.**—Refer to the figures in three or four advanced, well-illustrated texts. What do you see about these forms that would seem to ally them with the other cœlenterates? In what respects are they similar to the jelly-fish? In what respects dissimilar? What gives the name *Ctenophora* (comb-bearer) to the group? How does the gastro-vascular cavity compare with that of the other cœlenterates?

199. **The Body Organs and their Functions.**—Consisting as these animals do of a cylindrical body with a single central cavity, it is easy to see that the organization is still simple. All the organs are simple modifications of

this outer wall on the one hand or of this internal cavity on the other. Digestion and circulation take place in the cavity (gastro-vascular), and its entodermal cells absorb the food. Respiration, or the taking up of oxygen and the giving up of carbon dioxide, take place by means of the whole body surface. There are muscle fibers, both circular and longitudinal in the body wall. These are better developed in the higher forms. The nervous cells are either scattered over the body or grouped at the free end near the mouth and tentacles, or in the jelly-fishes around the margin of the umbrella. If there are any sense organs they are in the same regions.

Several things show us how lowly is the organization of this branch. We have seen how readily they bud and form new individuals. This shows that all the tissues are highly reproductive. This is not true of the most differentiated animals. Furthermore, numerous experiments on different members of the branch show us that they have great power of regenerating lost parts when these are cut away. The Hydra and other polyps may be cut into two or more pieces, and under favorable conditions each piece may become a perfect animal with all its proper parts. This again shows low organization.

200. **The Place of the Cœlenterates in Nature.**—The food of the cœlenterates consists largely of organic matter broken up by the waves, and of small, frequently microscopic, organisms. Since they are attached, their food must be brought to them either by currents and waves or by the motions of their prey. They must live therefore in regions where food is plentiful. There is no place in the whole earth where food is more plentiful than at the bottom of the ocean near the shore. All the passive

animals are more successful here. The long slender tentacles, sensitive to touch and continually waving about, are the organs by which the food is detected and caught.

The jelly-fish are used as food by fishes and whales, but they do not contain much nourishment since only about 1 per cent. of their body is solid matter. The other species do not seem to furnish much food for other animals. The red coral of the Mediterranean is used in making jewelry; this species does not secrete its skeleton as rapidly as the more common species.

Corals have added considerable land to the margins of continents by forming the fringing reefs a few miles from shore, as along the coast of Florida. The washings from the land finally fill up the space between, the plants begin to take root, and gradually a new body of marshy land fringes the old land. A large part of the peninsula of Florida has a coral foundation. This is true of many of the islands of the tropical seas.

201. Definition of the Cœlenterata.—The most marked characteristics of the group are: the single (gastro-vascular) cavity, lined with entoderm, which has only one opening (the mouth); there is no separate "body cavity" (see 122) as in the higher animals; they have their external organs (tentacles) and many of the internal structures arranged radially about the long axis, at the free end of which the mouth lies; the netting cells are the protective structures.

202. Key to the Classes of Cœlenterates.

True netting cells.

Mouth opening directly into gastro-vascular cavity.

Class I Hydrozoa.

Polyps attached; medusæ, when present, small.

Order Hydromedusæ.

No medusæ: example: *Hydra*.

Attached medusa-like bodies; examples: *Cordylophora*, *Plumularia*.

Medusæ escape and swim freely; examples: *Obelia*, *Bougainvillea*.

Polyps and medusa-like bodies united in a floating or free-swimming colony *Order Siphonophora*.

Example; Portuguese Man-of-war (*Physalia*).

Mouth, with ectodermal gullet leading to gastro-vascular cavity more or less divided by partitions.

Chiefly medusoid (jelly-fishes) *Class II Scyphozoa*.

Examples: *Aurelia*, *Lucernaria*.

Chiefly polyps..... *Class III Anthozoa*.

With partitions on plan of 6..... *Sub-class Hexacoralla*.

Solitary; no skeleton. Example: Sea Anemones.

Limy skeleton. Examples: Reef-forming corals, as *Madrepora*, *Astræa*, etc.

Partition on plan of 8 *Sub-class Octocoralla*.

Examples: Red Coral; "Dead-men's Fingers;" sea-fans.

Nettling cells modified into "adhesive cells"; jelly-like,

Class IV Ctenophora.

203. Topics for Themes in Zoology and English.—1.

Discuss the power of regenerating lost parts in *Hydra* and other species of coelenterates. The value and meaning of it.

2. Coral reefs—kinds and manner of formation. Kinds of corals that take part in this work.

3. Compare the different forms of organic colonies illustrated in this branch. Arrange them by beginning with the simplest and going to the most complex. What is the most complex instance that you are able to find?

4. Polymorphism and division of labor in the colonies. What different functions are apportioned to the different individuals? Which are retained by each individual?

5. What convinces you that the Portuguese man-of-war is a colony rather than an individual with complex organs?

6. Select some type, as *Obelia*, *Campanularia*, *Pennaria*, or *Aurelia*, and follow the life-cycle carefully in the reference books, studying the alternation of generation. Examine all the figures you can find of the species.

7. Are the cœlenterates strictly radially symmetrical?
8. What sense organs are described for the cœlenterates?
9. What is the manner of action of the nettling cells?
10. In what ways are the cœlenterates more highly organized than the sponges.
11. What arguments could you advance for the view that Hydra is descended from marine hydroids and has become adapted, in the course of time, to fresh water.
12. Why were these animals originally called zoophytes?

CHAPTER XVI.

UNSEGMENTED WORMS.

204. The forms described in this chapter do not belong to a single branch or phylum of the animal kingdom. Most zoologists regard them as sufficiently different in form and structure to make at least four branches. The species are not very numerous and the individuals are not large.

To the zoologist these small groups are interesting because:

1. They are the lowest of the many-celled animals that show a clear development of a long axis with anterior and posterior ends, right and left sides, and dorsal and ventral surfaces (*bilateral symmetry*).

2. The various divisions show, especially in their embryonic development, certain similarities to the well-recognized branches of animals; so it may be that some of the higher phyla sprang originally from types like these.

3. These groups have not been so thoroughly studied in the past as some of the more developed animals.

To the elementary student they are of interest because of their wide-spread occurrence on the face of the earth in all sorts of conditions and places; because so many of the harmful and dangerous parasites on man and the

domestic animals belong to some of these branches; and because of the tremendous power of reproduction and the striking metamorphoses they have in order to become adapted to their parasitic life. All have non-sexual methods of reproduction.

PHYLUM IV.—*Platyhelminthes* (or *Flat-worms*).

205. The *flat-worms* include three main types which differ very much in appearance and in their manner of living. They get their name from the ribbon shape.

The simplest division (*Planarians*) are aquatic free-swimming forms. They are found in stagnant water on the under surfaces

FIG. 52.—Diagrammatic sagittal section of *Microstomum*, showing a chain of four zooids (individuals) formed by fission. *b*, brain (the exponents indicate organs of progressively younger individuals); *d*, divisions (dissepiments); *e*, eyespot; *ent*, entoderm; *g*, gut; *gl*, glandular cells about the mouth; *m*ⁿ, mouth.

Questions on the Figure.—What convinces you that the zooids are of different age? Is the mouth formed from ectoderm or entoderm? Is the gut a blind sac? Describe the changes that would have to take place when these zooids separate and make independent worms. Why is this described as non-sexual reproduction? How does it differ from the non-sexual reproduction in the cœlenterates? What does *sagittal* mean?

of objects. They are covered with cilia, like the paramecium, and glide along through the water or swim vigorously by using the whole body. A general idea of their organs can be had from Figs. 52 and 53.

206. The second group (the *Trematodes*) are small and usually parasitic animals. Their metamorphosis is very complex and often takes them through two hosts at different periods of the cycle.

Different species have become adapted to different hosts, but the life of the liver-fluke of the sheep (*Distomum hepaticum*) is best known. It may be given briefly as follows (compare at each step with Fig. 54):

The adult fluke is found in the bile duct of the liver of the sheep, where it produces such disturbance as to cause disease and death.

FIG. 53.—Diagram of a planarian, showing the distribution of the digestive tract and the nervous system. *b*, brain with the pigmented "eyespot"; *c*, sensory cilia; *d*, a main division of the digestive tract; *d'*, the minuter divisions of the tract; *l.n.*, lateral nerve, from which fibres pass to the tissues; *m*, mouth; *r*, outlet of the reproductive bodies. The chief structures not shown are excretory system, reproductive organs, and the general body tissues.

Questions on the Figure.—How does this form compare in shape and symmetry with the jelly-fish and sea-anemone? What is the meaning to the animal of the much-branched digestive tract? Is there a body cavity? A circulatory system? (Consult references.)

Each worm may lay hundreds of thousands of eggs; but these eggs do not further infect the sheep. After fertilization and early development they pass out the bile duct into the intestine and thence to the outer world. If these embryos fall into water or get carried into water before they die, each develops into a free-swimming larva (Fig. 54, *c*). This animal can sustain itself only a short time

in the water. In order to develop it must find its way into the tissues of a particular species of pond-snail. Here it undergoes a series of rapid non-sexual reproductions, each time infesting the tissues of the snail more completely (Fig. 54, D-F), and ultimately bringing about its death. After reaching the *cercaria* stage (Fig. 54, G), it is free-swimming for a short while and then becomes encysted so as to enable it to await the time when it will be taken into the body of a sheep again, when it drinks the water. The cyst is then dissolved, the animals make their way to the liver and develop into the adult fluke (Fig. 54, I). It will be seen that this cycle illustrates both a metamorphosis and an alternation of generation. The student will notice how closely the organism is adapted to the life both of the sheep and the snail. Any failure to meet this special adaptation means death, and millions do fail to make connection. The tremendous power of reproduction is all that saves the species.

207. The third class (the *Cestodes* or tape-worms) are also parasitic and in a general way resemble the trematodes in the complexity of their life. In the adult they are found attached to the wall of the stomach or intestine of the host and consist of a long (often many feet in length) chain of bodies (*segments* or individuals). The oldest segments are furthest from the "head," or attached end (Fig. 55). Each of these units is a perfect sexual individual, having organs producing both eggs and sperm. The eggs are fertilized in the body and remain there during early development. They grow to such an extent that they gradually destroy the other organs and the oldest of the segments are merely cases, full of young embryos. These break off and escape at this stage. As this happens new segments are being formed just behind the "head," and thus the colony keeps its length. This will continue indefinitely as long as the head holds to the wall of the intestine and proper nourishment is supplied. It is provided with suckers or hooks for this purpose. There is no mouth, no digestive tract, no circulation. There is a nervous centre in the head, excretory tubes running the length of the colony, and very complex reproductive organs in each segment. There are numerous muscles, but there is no real locomotion.

In the life history the mature cases break away from the chain and escape to the outer world from the digestive tract of the host. If they are not taken up by some other animal this is the end of them. If swallowed by the proper host the embryo case is dissolved and the embryos escape and soon bore through the wall of the digestive tract into the circulation or directly into the tissues. Here they

FIG. 54.—A series of diagrams illustrating the life cycle in the LIVER FLUKE (*Distomum*). After Thomas, Leuckart, and others. *A*, egg in its case; *B*, early embryo, still in case; *C*, free-swimming ciliated embryo; *D*, same after encysting in tissues of snail (*sporocyst*); *E*, sporocyst at later stage producing by internal, non-sexual processes, new sporocysts, and *redia* (*r*) which break from the sporocyst and lead an independent life of their own in the tissues of the snail; *F*, a mature redia producing within itself new generations of redia, and a new type of larva, *cercaria* which escape by a birth-pore (*b.p.*) and make their way into the water; *G*, *cercaria*; *H*, same after losing its tail and becoming encysted; *I*, the young fluke in the liver of the sheep, where it becomes sexually mature and produces perhaps 500,000 new eggs. *b*, brain; *b.p.*, birth pore; *c*, cercaria; *c.m.*, cell masses,—embryos formed non-sexually within sporocysts and redia; *e*, eyespots; *ex.*, excretory tubules and pore (only the posterior portion shows); *g*, gut; *m*, mouth; *ph*, pharynx; *r*, redia; *s*, suckers; *sc*, sporocyst; +, stages in which non-sexual reproduction occurs; *, stage at which sexual reproduction occurs.

Questions on the Figures.—In which stages are eyespots found? Number and position of the suckers? In which stages found? What is the result of increasing the points at which reproduction occurs in the cycle? Is this a combination of metamorphosis and alternation of generation? Your reasons for your answer? Compare this with the life history of the tape-worm. Note the encysted stage by which it passes from water to its host in each instance.

FIG. 54.

grow into a form known as the *bladder-worm* (Fig. 55, A) and encyst in the tissues. They do not reproduce in this second host, however, as in the case of the trematode. They have no power of further development so long as they are in the flesh of the new host. This flesh must be eaten by the appropriate carnivorous animal before the worm can come back to its adult condition again. It will be seen that at least one of the hosts of the tape-worm must be a flesh eater. In one species of the tape-worm this cycle is completed by man and the hog as hosts; in another by man and the ox; there are others that use the dog and various ruminants; the cat and the mouse; the dog and the rabbit; the shark and other fishes, etc.

FIG. 55.—Diagram showing stages in the life history of a tape-worm (*Taenia*). A and B, bladder-worm stages. C, the adult worm consisting of a chain of "segments" or individuals in various stages of maturity. D, a young embryo such as fill the uterus of a mature case. b, bladder; ex, excretory canals; g, reproductive pore; h, head, provided with suckers and hooks; u, uterus in a mature individual; z, zone of fission where new individuals are formed.

Questions on the Figures.—What arguments can you find for considering the whole object an individual? for considering it a colony? Where does non-sexual reproduction occur? Where sexual? If the numbers represent the approximate position of the segments, what proportion of the worm is omitted in the drawing?

PHYLUM V.—*Nemathelminthes* (or Round Worms).

208. Practical Library Exercise.—Consult several more extended texts as to the life history of *Trichina*. What are its hosts? What part of its life does it spend with each? To what extent does it reproduce in each? In which is the sexual phase? Is there an alternation of generation as well as a metamorphosis? What is the nature of the disease called *trichinosis*? How is it to be avoided with certainty?

Similarly, study the life history of *Ascaris*.

What are the chief differences in form and structure between the round worms and the flat worms? Are the round worms all parasitic?

PHYLUM VI.—*Trochelminthes* (or *Rotifers*).

209. **Practical Exercises** (for laboratory and library).—Rotifers are almost certain to appear in the water of some of the jars in the laboratory. They are small and require the microscope. Time should not be taken to study them thoroughly, but the following items may be considered:

What is the general form? Does it change? How does the anterior end differ from the posterior? Are they symmetrical? Find the feature that gives them their name (*rotifers*, or wheel-bearers). Where is the mouth? Follow the course of the digestive tract. Note the object just back of the mouth which is continually at work. What is its nature? Is there an anal opening?

In what various ways do the animals move? Are they sensitive? Do they take food? What kind?

By examining the figures see what range of form is found in the group. What qualities are constant? How do they reproduce? Do you find any signs of segmentation of the body at all? Where are rotifers found in nature?

PHYLUM VII.—*Molluscoidea* (*Polyzoa and Brachiopods*).

210. **Library Exercise**.—Where are these animals found? What are the similarities and what the differences between the Polyzoa and the Brachiopoda? What are the meanings of the names? Show these points by means of parallel columns.

What is the geological history and importance of the brachiopods? Where were they formerly classed? Why? Why removed from that classification?

211. **The Place of the Unsegmented Worms in Nature**.—These animals represent the most varied modes of life. The planarians are terrestrial, fresh-water, and marine; the rotifers are free and occur chiefly in fresh water; the polyzoans are aquatic and colonial animals looking much like the hydrozoa, when we consider the colony as a whole; the brachiopods are marine and may be attached, but are not colonial; the trematodes and cestodes represent all possible degrees of parasitism on all sorts of animals. These animals are found almost over the earth, which suggests that they are old and successful types. There is probably not a single group of the higher forms that escapes being the host of one or more species of these worms. The organs most commonly infested by the parasites are the digestive tract and its glands, as the liver, the blood vessels, the body cavity, and certain tissues in which the blood supply is

great. The parasites produce all sorts of disturbances, from mere inconvenience and functional derangement, such as anemia and fevers, to the complete destruction of organs.

In protecting himself from most of these parasites, man has a complete means of escape by the perfect cooking of the meats which he uses. Rare beef and uncooked pork are the chief means of infection.

212. Topics for Themes in Zoology or English.—1. Consider the economic importance to man of the parasites included in this chapter.

2. Make a table of all the worm parasites you can find description of, giving the following facts: the name; the host in the mature or sexual stage; the position in the body and the results on this host; the host in the non-sexual stage; its position and the results to the host.

3. Give an account of the hook-worm of the Southern States. How do human beings become infected by it? What part of the body does it attack? What are the symptoms of the disease?

4. Give an account of the methods whereby man may protect himself from each of the principal parasites mentioned in this chapter.

5. Illustrate from this group the degeneration of organs that comes from the parasitic habit of life.

6. In what ways do the intestinal parasites in this group adhere to the wall of the digestive tract?

7. Prepare for the class, and draw on the board, a diagram of the reproductive organs of the tape-worm, indicating the function of each portion of it.

8. What arguments could you advance for considering the tape-worm a segmented individual? For considering it a colony of individuals? Similarly for the animal figured in Fig. 9?

CHAPTER XVII.

PHYLUM VIII: ANNULATA (OR SEGMENTED WORMS).

213. **General Survey.**—The segmented worms include the earthworms, many minute fresh-water worms, the leeches, and numerous marine worms. They are scattered over the earth and are adapted to many manners of living. They all have elongated bodies, and the great majority of them burrow in the soil or sand, or swim freely through the water. Some of the sea-worms, however, bore into more solid objects and remain permanently in their burrows, extending only the front part of the body from the tubes in search of oxygen and food. These occur in great numbers among the sponges and coral reefs. The worms furnish food for a great many other animals, and they in turn live on decaying organic matter and on the minute plant and animal life that is found in the waters.

The structural qualities that make them interesting to the student are as follows:

1. They are bilaterally symmetrical and the anterior end shows a more highly developed head than in any of the phyla which we have yet studied.

2. The outside of the body shows a series of rings, or segments, one after another in the long axis of the body. This is known as *segmentation*. The segments are much more alike than those we studied in the crayfish (Ch. VIII). Several internal organs are segmented also.

3. While the outside does not show it, the internal

organs of digestion, circulation, the nervous system and sense organs, excretory system, and the like, are better differentiated than in the phyla that have been studied.

4. There is a well-developed body-cavity in which the internal organs lie.

214. **The Earthworm.**—**Practical Exercises for Field and Library.**—*Habits.*—Where are earthworms to be found? In what kinds of soil? How do the worms get through the soil? What becomes of the dirt that was originally in the burrows? Make a life-box not more than one-half inch in width, with glass sides, and fill with moist earth. Put in this a number of worms and the underground activities can be watched. How do they behave as the soil dries at the top? Moisten it from the top.

Locomotion.—How do the earthworms move? Place one on a moist surface and watch carefully every motion, so as to determine just how the crawling is done. Set down, in order, the steps. Would you say that there are any special organs of locomotion? Can he move with either end foremost? What determines which will go forward? Study, in the figures of your text-books, a cross-section of the body of the animal. How are the muscles arranged? Will this help you understand the actions? Identify the setæ. Where are they found?

General Form and Structure.—Make a list mentioning all the facts of external differentiation you can discover? Would you say that the worm is simple or complex, externally? Compare with the grasshopper in this respect. Is it symmetrical? What paired organs can you find? What differences in structure and behavior between the anterior and the posterior ends? Between the dorsal and ventral surfaces?

Is the number of segments the same in the different specimens? Are the segments all alike? How many depart in some way from the general average? Where are these? Have these different segments any special meaning? Can you distinguish special regions in the body, as you did in the crayfish or grasshopper? Locate the mouth, the anal opening, the girdle (*clitellum*).

Make such drawings as are necessary to show the general external structure.

What color is the animal? What produces the color? Are all equally transparent? Can you see any organs at all through the body wall?

Sensitiveness and the Nervous Organs.—Devise experiments to test

whether the earthworm knows the difference between light and darkness. Which does it prefer? Has it any eyes? Test with a bristle to see whether it is sensitive to touch. Is it equally so at all parts of the body? Can it recognize moist soil as compared with dry? Test. Of what value would such a power be in life? Can it

FIG. 56.—Longitudinal section of anterior end of *Dero*. A, sagittal section; B, frontal section, showing anterior part of nervous system. *b*, brain; *co*, nervous collar about the mouth; *c.v.*, contractile blood vessels ("hearts"); *d*, dissepiment; *d.m.*, dermo-muscular wall; *d.v.*, dorsal blood vessel; *m*, mouth; *n.c.*, nerve cells; *n.f.*, nerve fibres; *np*, nephridia; *p*, prostomium; *ph*, pharynx; *s*, setae; *sn*, segmental nerves; *v.g.*, ventral chain of ganglia; *v.v.*, ventral blood vessel. Only a part of the nervous system and of the blood vessels belonging to the figure is shown.

Questions on the Figure.—Compare this with a cross-section of *Dero* (Fig. 57) and identify the parts. How do the four anterior segments differ from the others figured? Does the nervous system continue the whole length of an animal like this? What organs continue through all the segments? Which are *repeated* in practically all the segments? Which are confined to a few segments? How do the segments in *Dero* compare with those of the tape-worm?

taste or smell? Can you test in such a way as to be sure of the difference?

The nervous system may be studied from figures in the text-books. See Figs. 56 and 57. There is a nerve-center (*brain*) just above the mouth. This is connected with a chain of nerve centers, on the floor of the body cavity, by a loop of nerve fibres. Every

segment of the body has a small nerve-center of its own in this ventral chain, from which the nerves pass to the muscles and other organs in the segment. The snout and lips receive nerves from the brain.

The Body Cavity.—Inside the body wall there is a roomy cavity in which all the internal organs lie (Fig. 57, c). The long digestive tube runs from one end to the other of this cavity. The cavity is divided up into as many chambers as there are segments, by means

FIG. 57.—Transverse section of *Dero*. $\times 300$. c, coelom; d.m., the body wall, consisting of skin and muscles; d.v., dorsal blood vessel; ect, ectoderm; ent, entoderm; g, gut; g.f., large nerve fibres; gl, glandular cells assisting in digestion; m.c., circular muscle fibres; m.l., longitudinal muscle fibres; n, nephridium; n.v., ventral nerve chain, made up of nerve cells and fibres; s, setæ; v.v., ventral blood vessel.

Questions on the Figure.—Compare this with Fig. 56 and identify all the structures that appear in both. What work can the longitudinal and circular muscle fibres do? What motions have the setæ? How produced?

of thin circular partitions (Fig. 56, d) that run from the wall to the digestive tract. The cavity contains a fluid similar to the blood.

The Digestive Tube.—How nearly does it fill the body cavity? How many different regions can you make out, either from dissection or from figures in the texts? In what particulars do they differ? What names are given to them by the anatomists? What is the function of each region? Does the tube show any signs of segmentation corresponding to that outside?

Circulation and Its Organs.—Can you see the dorsal blood vessel through the body wall in the living specimen? Look at several. Is there any trace of pulsations? Compress the worm slightly and see if you can discover any other vessels. There is a ventral vessel which may be seen under favorable condition. There are also several circular vessels (*hearts*) looping the digestive tube and connecting the dorsal and ventral vessels (Fig. 56, *c.v*). In what direction does the blood flow in the main vessels? There are numerous other smaller vessels, with capillaries in the body wall, in the walls of the digestive tract, and of the excretory tubules. What are the functions of each of these sets of capillaries?

Excretion and the Excretory Organs.—In Fig. 13 is seen a diagram of an excretory tubule of a worm. How many of these in the earthworm? How are they arranged? How are they supposed to do their work?

Reproduction and Development.—The earthworm contains both sets of sexual organs in one individual. They are too complex for the elementary student to work out by dissection. While an individual produces both eggs and sperm there are special devices to insure that the eggs will never be fertilized by the sperm from the same individual. The eggs, together with sperm from another individual, are deposited in a cocoon or capsule which is secreted by the glands of the girdle. Within this capsule the eggs hatch and the early development takes place. They do not all develop, however; some get the start and live upon the others. Make a separate outline drawing of each set of organs in the earthworm and compare it with the corresponding structures in the crayfish. Make a diagram of an imaginary sagittal (*i. e.*, median longitudinal, dorso-ventral) section, showing all the structures that should show in such a section.

215. It will be seen from the preceding studies that the earthworm has specialized organs for each of the great animal functions except those of locomotion and respiration. The body wall itself takes care of both of these functions. The setæ are used in locomotion, but can hardly be called organs of locomotion.

216. **The Minute Fresh-water Worms.**—There are a large number of small types of worms similar to the earthworm, but on the whole more simple in their struc-

ture and manner of living. The most of them are transparent and are therefore beautiful objects of study under the microscope. Their setæ are better developed than those of the earthworm, and their nervous system and sensory organs are often better developed also. Many have spots of pigment known as eyes. *Dero*, Fig. 58, is one of these worms.

217. **Marine Annelids.**—Many of the segmented worms live in the ocean. These are rather more highly developed in many ways than the earthworms. They have better organs of locomotion, having many bristles on definite leg-like projections of the body wall. The head region is also more specialized, often having eyes, tentacles, and

FIG. 58.—*Dero*, a fresh-water oligochaetous annelid, in optical section. Enlarged about 30 times. Trace out structures already lettered in Figs. 56 and 57. *oe*, oesophagus; *p*, pavilion lined with ciliated entoderm; *pr*, outgrowth from the anal segment; *z*, a zone in front of anal segment in which new segments are being formed; *z'*, an old segment in the middle of the body that is developing a division of the worm into two. The anterior half of *z'* will produce a region like *z* for the anterior individual. The posterior half of *z'* will produce a head and four segments like 1-4 of the parent worm.

Questions on the Figure.—Trace the differentiations of the digestive tract. Follow carefully just what must take place in the dividing segment (*z'*) in this process of forming two worms.

biting jaws for the holding of prey. They also have special outgrowths of the body wall, in the form of thin gill-like structures, for the purpose of respiration. There are two main types of the marine worms—the free-swimming forms such as the sand worms (*Nereis*), and the tube worms (as *Amphitrite*, Fig. 59). The latter may burrow

FIG. 59.—*Amphitrite ornata*, from Verrill. A tube-dwelling annelid.

Questions on the Figure.—What is the nature of the outgrowths at the anterior end? What functions might they have? Consult reference texts.

in the sand and make their tubes there, or may form solid tubes of limy matter (as *Serpula*). In the fixed forms the head region is even more highly specialized. The tentacle and gills are located here, and sometimes they come to have an enormous length and number.

218. **Leeches.**—These animals live in water, have no setæ, are usually temporary parasites in habit, and have

two sucking discs whereby they may attach themselves to the host. They have a peculiar enlargement of the digestive tract that enables them to swallow large amounts of blood on which they may live for many days (Fig. 61).

FIG. 60.—*Cirratulus grandis*, from Verrill.

Questions on the Figure.—What evidence have you that this is a chaetopod? Compare this form with the preceding at all points.

219. Non-sexual Reproduction and Regeneration of Lost Parts.—Many of the worms, both of the marine and fresh-water kinds, have the power to develop into two or more worms by producing a new tail and head in the middle of the body. This usually takes place in one segment; the anterior half of it makes a tail for the forward worm and the posterior makes a head for the hinder one (Fig. 58). They may remain together until a chain of four or more have formed. They finally separate and

lead independent lives. This is not found in the earthworm and leeches. But even in these there is great power of reproducing lost tissues that have been cut away. For example, an earthworm may have the first 6 or 8 segments, including the mouth and brain, removed and if kept under favorable conditions will gradually re-form all

FIG. 61.—Outline drawing of a leech (*Clepsine*).

Questions on the Figure.—Which is anterior and which posterior end? Are the external markings true signs of segmentation in leeches? Where are the suckers in this animal? Is this its permanent shape? How does it move?

the head organs and be enabled to live its independent life again. The same is true of the posterior region. Both of these powers point to the fact that they are of lowly organization.

220. *Definition of the Annulata.*—The most important characteristics of the group are: the well-segmented body;

appendages when present of simple bristles, not jointed like the legs of the grasshopper; the large, well-developed body cavity; and the paired tubules of excretion.

221. Classification of Segmented Worms.

Setæ present Class *Chaetopoda*.

Setæ few and simple Sub-class *Oligochæta*.

Small, chiefly aquatic Order *Naidomorpha*.

Examples: Nais, Dero, Tubifex.

Larger, living chiefly in the soil . . . Order *Lumbricomorpha*.

Examples: Earthworms.

(Lumbricus; Allolobophora; Diplocardia).

Setæ numerous, on a complex foot-like organ.

Sub-class *Polychæta*.

Free-swimming; head distinct; carnivorous.

Order *Errantia* (wandering).

Example: Nereis, the sand-worm.

Tube-living; head not distinct; not actively carnivorous.

Order *Sedentaria* (fixed).

Examples: Amphitrite; Cirratulus; Serpula.

Setæ wanting; suckers present Class *Discophora*.

Examples:

Hirudo medicinalis, a parasite.

Aulostoma, free and carnivorous.

Hæmidipsa, a land leech.

222. Topics for Themes in Zoology or English.—I.

Compare the "segments" in the segmented worms and the tape-worm.

2. What organs in the worm are derived from ectoderm? from entoderm? from mesoderm?

3. In the chaetopods what sets of organs pass through all the segments? Which are repeated in nearly all? Which are limited to a few?

4. In what ways do earthworms benefit the soil? Read portions of Darwin's "Formation of Vegetable Mould."

5. Why is the anterior end of the digestive tract of the earthworm more highly differentiated than the posterior end?

6. Investigate parasitism among the annulata.
7. In what different ways is respiration effected in the group? What is the relation of the method to the life habits of the animal in each case?
8. Enumerate the various ways in which it seems to you the earthworm is especially adapted to its particular method of life.
9. Make a report on reproduction by division (*fission*) in this group. What are the chief points of difference in the different species?
10. How is cross-fertilization secured in the earthworm?
11. Compare the earthworm and hydra as to the relation between the digestive cavity and the body wall. How do the tissues get the digested food in each case?
12. Select and undertake some special spring studies as to the habits and behavior of some members of this group.
13. Of what value are worms as food to the higher animals?

CHAPTER XVIII.

PHYLUM IX: ECHINODERMATA.

223. **General Survey.**—This branch of animals is found only in the sea. It is perhaps the easiest of the lower groups for the beginner to recognize. While its members differ a great deal in general form, they usually have 5 (sometimes more) rays, or rows of structures, running radially from the mouth outward. In the simplest types these radial parts are in definite arms, as in the common starfish (Fig. 62). Usually the body is covered with spines which are attached to bony plates in the body wall (hence the name *echinoderm*). Common names of the classes in the branch are: starfishes, sea-urchins, brittle-stars, sea-lilies, sea-cucumbers.

In addition to the radial symmetry and the spiny skin, the following facts make the group interesting to the student: There is no head properly speaking, the mouth being located in the middle point from which the rays diverge; all the members of the group are sluggish and very poor movers, in the adult; the young are bilaterally symmetrical and have to pass through a metamorphosis before they become radiate.

224. **Starfish: a Practical Exercise for the Laboratory.**—Dry specimens will serve for this study, but one or more alcoholic specimens will be valuable.

General Form.—Indicate the signs of radial symmetry. Is there a central disc? If so, how large is it in relation to the arms? Along how many lines can you divide the

animal into halves? Where are the ends of these lines (*axes*)? The arm is known as a *radius*; the space between two arms is an *inter-radius*.

FIG. 62.—Starfish, after Leuckart and Nitsche.

Questions on the Figure.—How would you describe the symmetry of this form? Compare the figure with the diagrams and the text, and identify all the structures and regions which show in the figure. Compare with figures of other species of starfish and note the contrast in disc, arms, etc.

The External Organs.—Which is the upper surface in life? Reasons for your view? Locate the mouth. This surface is known as the *oral* surface; the opposite is the *aboral*. Examine these two surfaces with care and note every structure found on either surface, and the differences

between the surfaces. How many different types of spines do you find? Are the spines arranged in the same way everywhere? What portions of the body have no spines? What takes the place of the spines here? Are these structures hard or soft in life? What is the appearance of the madreporic body under a lens? Are there any smaller structures among the spines on the aboral surface? Examine with a lens.

Make a sketch from the aboral view, drawing the spines on the disc and one arm. Make a similar diagram of the oral surface showing the mouth, the ambulacral groove, the ambulacral feet, etc. (See Fig. 62.)

225. A Library Exercise.—A comparative study of the general form and external features of the five representatives.

Rule a sheet of paper with five vertical columns. At the head of these columns put the words starfish, sea-urchins, brittle-stars, sea-lilies, sea-cucumbers. By reference to figures and descriptions in the texts, determine the condition in each of these groups with respect to the following features, and insert the facts under their appropriate columns:

1. The symmetry and general form of the body. Length and position in nature of the oral-aboral axis.
2. The degree of development of the arms, their form, size, and relation to the disc.
3. Degree of development and character of the skeleton and spines.
4. Position of the mouth and anus.
5. Position of the madreporic body.
6. Character, position, and use of the ambulacral feet.

226. The Interior of the Body.—As in the earthworm, if one cuts through the body wall (which is made up of the skin and the muscular elements among which bony plates may be formed) he finds a large body cavity in which the internal organs lie. This body cavity is largest in the disc; it may or may not pass out into the arms. It contains a fluid similar to that found in the poorly developed blood vessels. The principal organs found in the body cavity are the digestive organs and the reproductive organs (Figs. 63 and 64).

227. The Digestive System.—The nature of the digestive tube in animals is always adjusted to the nature of the food used. In the

opening on the aboral surface completes the tube. Trace these structures in Fig. 63.

In the sea-urchin the mouth apparatus is much more complex; and the tube is much longer, as is also the case in the sea-cucumbers, but it is a good deal more simple and uniform.

230. The Water-vascular System and its Functions.—This system is a device found in no other group of animals. It is the most distinctive feature of the echinoderms. It is a series of vessels

FIG. 64.—Transverse section of arm of a starfish, near the disc. Lettering as in preceding figure. *a. r.*, ambulacral rafter; *ov.*, ovary, containing ova.

Questions on Figures 63 and 64.—What are the chief systems of organs that have parts in the disc of the starfish? Which of these have radial portions going into the arms? Follow carefully the ectodermal, entodermal, and mesodermal boundaries. Locate and identify the various structures lettered and determine as far as possible whether the essential part of each is furnished by entoderm, ectoderm, or mesoderm. Is there a coelom? Your evidences?

communicating (usually) with the outside world, by means of the *madrepore body* found on the aboral surface in the starfish. The vessels contain sea-water, except in the sea-cucumbers, in which they contain the same kind of fluid that is found in the body cavity.

In the starfish a tube runs from the madrepore body toward the mouth (*stone canal*, Fig. 65, *s*). It communicates with a circular tube running around the mouth (Fig. 65, *r. c*). From the *circular*

canal, *radial canals* pass out into each arm (Fig. 65, *r. t.*). The radial canals in their turn become distributing centers, passing the water sidewise into bulbs (*ampullæ*, Fig. 65, *a*) which are the inner end of the *ambulacral feet* which were seen in the external studies of the starfish, in the grooves on the oral surface. The feet are constructed in such a way as to have a sucking disc at the free end, and it is by the attachment of hundreds of these that the animal holds to solid objects and crawls in its slow fashion. Its arms are also flexible, and if placed on its back, it can turn the end of the arm so that a few

FIG. 65.—Diagram of a portion of the water-vascular system of a starfish, taken alone. *a*, ampulla; *f*, ambulacral feet; *m*, madreporic body; *p*, Polian vesicles; *r.c.*, ring canal, with the upper portion removed at the right; *r.t.*, radial water tubes; *s*, stone canal.

Questions on the Figure.—Where does the water enter the system? Write the parts enumerated above in their proper order, commencing with the point of entrance. At what points is the system really of use to the animal? In what various ways is the water-vascular system believed to be of use in the different classes?

feet can be attached to the solid surface, and by further bending and further attachment of feet and the combined muscular pull in the fibres of the feet themselves, it can finally right itself.

The sea-urchins use their spines in moving, since in this case the spines are fitted with a kind of ball and socket joint and have muscles. The brittle stars move about in a slow and clumsy fashion, by using their slender arms as feet. The sea-cucumbers use the ambulacral feet in motion; or in certain burrowing types they burrow by the muscular movements of the body alone. The sea-lilies are typically attached, like plants, and only have the motion of waving arms or bending stalks.

FIG. 66.—Diagram showing the arrangement of the nervous matter in the starfish. *c*, central nervous ring about the mouth (*o*); *r.n.*, radial nerve in each arm (see *r.n.* in Fig. 64).

Questions on the Figure.—Compare this arrangement of nervous matter with that seen in *Dero* (Figs. 56, 57). What similarity? What differences?

In some cases the tube-feet are modified into tentacles, and it is probable that in most forms they are more or less sensitive. They likely aid the animals in respiration also. Other thin projections of the body wall (Fig. 63, *d. b*), known as *branchiæ*, aid in respiration.

231. Reproduction and Development.—The sexes are distinct and the eggs are laid in the water, where they are fertilized. They develop into free-swimming gastrulas of very regular form. Later they develop into very characteristic bilaterally symmetrical larvæ (Fig. 67), which swim freely in the water for a few weeks and then settle to the bottom. They become attached to something and undergo a metamorphosis in which the adult radially symmetrical animal is formed. Radial symmetry is a form of symmetry suiting animals

to a fixed or sluggish life. Bilateral symmetry is the symmetry of moving animals, and is regarded as of a higher type. It therefore looks as though the echinoderms deteriorate as to symmetry during their embryonic development. This is taken by some naturalists as meaning that the whole group was once bilateral, and is now really lower in the scale in this respect than its ancestors were.

While there is probably no power to form new individuals by fission as in the worms, it is known that some starfish may regenerate new arms when these are broken away. It is claimed that an arm may even regenerate a new disc, and thus a starfish torn to pieces may make several new ones.

FIG. 67.—Diagrams of larval stages in two echinoderms, showing the bilateral condition. *a*, arms; *an*, anus; *m*, mouth.

Questions on the Figure.—Enumerate the points showing bilateral symmetry.

232. Definition of the Echinodermata.—There is great difference between the five principal classes of this group, but they are especially noted for the five-fold plan of the body organs, whether they are strictly radial or not; and for the water vascular system. The principal organs have their main portions in this central disc: as the digestive, the nervous, the water vascular, the body cavity. There may be portions passing into the arms, but these are branches of the central part. This brings it about that there is nothing which can properly be called a head. What corresponds to the head of other animals is in the center of the body.

233. Classification of Echinodermata.

Stalked; usually attached; mouth turned upward.

Class Crinoidea.

Examples: Sea-lilies; *Antedon*, *Pentacrinus*; *Metacrinus*.

Not attached.

Oral-aboral axis short and usually vertical.

Body with arms extending from a central disc.

Arms with ambulacral groove *Class Asteroidea.*

Examples: Starfish; *Asterias*, *Solaster*.

Arms without an ambulacral groove . . . *Class Ophiuroidea.*

Examples: Brittle stars; *Amphiura*, *Astrophyton*.

Spherical or flattened body with no free arms. *Class Echinoidea.*

Examples: Sea-urchins and sand-dollars; *Echinus*, *Strongylocentrotus*, *Clypeaster*.

Oral-aboral axis elongated, usually horizontal.

Class Holothuroidea.

Examples: Sea-cucumbers; *Holothuria*, *Cucumaria*, *Pentacta*.

234. Topics for Themes in Zoology and English.—I.

Report on the habits, appearance, and abundance of the crinoids in geological times.

2. Define *autotomy*. What is known of its occurrence in this group? Of what possible advantage would this power, coupled with power of regeneration, be to a species?

3. Study the echinoderms as a group that has degenerated from its original condition. What are its present adaptations to a sluggish life?

4. From a study of figures in the texts and of specimens in museums, find a tendency on the part of some sea-urchins to become bilaterally symmetrical in the adult.

5. Write an account of the protective structures on the surface of echinoderms, and of their probable functions, including spines and pedicellariæ.

6. Compare representatives of each of the five classes in the following respects: the nature of the mouth and the parts of the digestive tract; the powers of locomotion; respiration, and the metamorphosis.

7. The nervous system and the organs of special sense in echinoderms.

CHAPTER XIX.

PHYLUM X: MOLLUSCA.

235. **General Survey.**—The animals in this group are more complex in their organization than any we have yet studied. They include snails, mussels, clams, devil-fish, and squid. They differ radically from the echinoderms in that they are not radially symmetrical; they differ from the Annulata in that they do not have segmented bodies. They are not often attached, though most of them are sluggish and very poor movers. They are largely aquatic or frequenters of moist places, though some are able to withstand drouth for a time by reason of their shells. Wherever exposed, the skin of mollusks is soft and slimy, and within the shell the whole body is soft. From this fact their name is derived.

In general shape and external appearance the mollusks are very varied. There is little in the outer features of the clam and the snail and the devil-fish to indicate that they are related, but there are some fundamental things in which they do agree, and these differences in body are but the evidence of the very different mode of life to which they have become adjusted. In addition, the interesting points in which the mollusks agree are:

1. There is a fold of the body wall and skin, called the *mantle*, which develops about the body in such a way as to enclose a space (*mantle chamber*) in which the breathing structures (*gills*) lie. The outer surface of the mantle usually has glands that secrete a limy material which forms

the shell, which is so often thought of as being the principal mark of a mollusk.

2. While there are no paired legs, as in the grasshopper, the body produces a thickening, quite different in shape in different types, called a *foot*. This is seen in the crawling disc of the snail and in the large tentacles of the squid.

There are three important divisions or classes of the branch of mollusks:

1. The *Lamellibranchiata*, or clams, mussels, oysters, etc., which usually have two parts to the shell. These open and shut by means of a hinge worked by muscles. These are the lowest mollusks. They seem degenerate in some ways.

2. *Gasteropoda*, or the snails, whelks, periwinkles, slugs, in which the shell is in one piece. This is usually of a spiral form. The animal can draw itself into the shell or crawl partly out of it as its needs suggest.

3. *Cephalopoda*, or the squid, the devil-fish, the nautilus. These are the highest and most specialized mollusks, and probably the highest invertebrates. The majority of the living forms do not have an external shell, though the nautilus does. They are chiefly remarkable for the development of the head, which has a great array of tentacles (Figs. 77 and 78) about the mouth. These tentacles are believed to be a modification of the foot in the other forms.

236. How many specimens of Mollusca did you find in your collecting tours (Chapter II)? To which of these classes did they belong? Where were they found? What did you discover of their habits? Get together all the notes you have on them.

237. The Fresh-water Clam (Any Species): a Practical Study.—The mollusks are not a good group for dissection by an elementary class; and no single specimen which might be dissected will give a fair idea of the branch as a whole. It will be better therefore to study only the external appearance and general form of several types.

Get both parts of a clam shell. Make a complete study of the outside, noting all the markings and differentiations of parts that can be seen. Make an outline diagram. Study the interior of the shells in the same way. Compare internal and external finish and markings. Are the shells strictly symmetrical? Interpret the meaning of all the internal markings. Compare with texts and see if your interpretation is correct. Is a shell, from which the animal has recently decayed, normally open or shut? What causes it to be so? After studying a living specimen and one that has been cut open, see if you can answer the following questions: Does the shell grow? If so, how? What is the oldest point? Evidences. Have you any way of determining which is the right and which the left shell? What other facts must you determine first? See if you can determine them from the animal within. Have the muscles which close the shells always been where they are now? Evidences.

Examine briefly the soft parts of the animal within. Identify the mantle; the sheet-like gills (from which the name *lamellibranch*); the thick, muscular foot; the closing muscles; the anterior end; the ventral surface. What organ produces the shell? Can you justly say that the animal has a *head*?

Compare a snail-shell, point by point, with the clam. Enumerate the items of similarity; those of difference. Compare your notes on shells in Chapter IV.

238. Library and Museum Exercise: a Comparison of the Clam, Snail, and Squid, in General Habits and Organization.—Make rulings for a parallel-column study such as was indicated in section 225, and record the results of your study of these three animals in the following particulars: the symmetry and general shape of the body; head and its organs; the kind of food used and the method of getting it; the mantle and its different uses; the shell, its degree of development and the method of using; the contents of the mantle cavity; the foot, its parts and the

uses it is put to; respiration, how accomplished; locomotion, organs of, and their efficiency; the amount of food in the egg and the manner of development.

One topic might be assigned to each student, if the time is short, and a special report be brought on each topic before the whole class.

239. **The internal organization** of the mollusks is the most complex we have encountered in the branches we have studied. All the important functions have specialized organs, and some of them are highly specialized. The circulatory system, for example, is superior even to that of the next branch—the arthropods, to which the crayfish belongs. The respiration may take place through the wall of the mantle, or by means of gills (water-breathers), or by a sac (air-breathers). These structures, while in the mantle chamber, are not in the body proper. Within the body are digestive organs, special kidneys or excretory organs, reproductive organs which are often very complex, and the nervous system. The body cavity is not so large as in the segmented worms.

240. **The Digestive Organs.**—These differ greatly in accordance with the food used and the general structure of the animal. There is both a mouth and an anal opening, and the digestive tube usually runs the length of the body. In some forms, especially those in spiral shells, the tube passes up the spiral, turns, and comes back, opening close to the mouth. The snails have a roughened ribbon-like tongue by means of which they rasp off the substance of the leaves and other objects on which they feed. The clams have only a hole in the wall, to which cilia waft the small particles of food carried by the waters. There are no teeth, no tongue, no tentacles for holding food. The cephalopods have powerful beak-like jaws, suited to their carnivorous habit. There are always specialized stomach and intestine, and usually a crop in front of the stomach. The principal glands of digestion are salivary glands opening near the mouth, and the liver, which is often very large.

241. **Circulatory Organs.**—The heart in the mollusks has a muscular ventricle which pumps the blood into the arteries. The heart handles pure blood after it has passed through the gills. Auricles (varying from one to four) receive the blood from the veins and return it to the ventricle. The blood passes by way of the arteries to the capillaries of the system in the various tissues of the body;

from here it is brought by a series of blood spaces to the kidneys where the urea is excreted; it next goes to the gills where it loses carbon dioxide and gains oxygen. From the gills it goes directly to the auricles. In the clam some of the blood goes directly to the mantle and returns as directly to the heart. The accompanying diagram (Fig. 68) will assist the student in following the course of the blood. The blood cells are colorless. If there is color in the blood it is in the plasma.

FIG. 68.—Diagram showing the general course of the blood in a Lamellibranch. Only a short section is shown. *a*, auricle (right), with a slit into the ventricle; *b*, the body (region of spaces, tissues, capillaries); *g*, the region of the gills, with capillaries; *k*, kidneys, with capillaries; *m*, mantle; *v*, the ventricle from which arteries pass forward and backward; *v.c.*, "vena cava," in which the blood collects on returning from the tissues of the body.

Questions on the Figure.—Follow the general course of the blood by means of the arrows and letters. How many sets of capillaries are passed by the blood that goes to the mantle before returning to the heart? How many by that which goes to the system? What change takes place in the capillaries of the various regions? Why does that which goes to the mantle not need to pass through the gills?

242. **The Nervous System.**—There are some features of the nervous system that are fairly constant for the whole branch. There are three pairs of principal ganglia or nerve centers (Fig. 70): One pair in the region of the mouth above the gullet (*cerebral*); one in the foot (*pedal*); and one, posterior to either of these, controlling the internal organs and functions (*pleuro-visceral*). There may be other ganglia, but these are the foundations of the system. They are connected by means of loops of nerve fibres (see Fig. 70). In the cephalopods these loops are very short and the ganglia are brought together into a well-organized brain in the head. This massing of the ganglia in one place is associated with the good development of the head-organs in the squid, and is a measure of its high place among the invertebrates.

FIG. 69.—Shell of a bivalve mollusk, inner surface. *ad.a.*, depression showing point of attachment of the anterior adductor muscle; *ad.p.*, posterior adductor muscle; *h*, hinge, with teeth; *l*, attachments of the ligaments; *p*, pallial line, marking the attachment of the muscles of the mantle; *s*, pallial sinus, marking the attachment of the retractor muscles of the siphon; *u*, umbo or beak.

Questions on the Figure.—Which is the dorsal and which the ventral portion of the shell? Is this the right or left valve? Is there any other fact that you will have to determine before you can answer? What are the adductor muscles? What is their function? Of what use are the teeth on the hinge? What is the siphon? To what point in the shell of the snail does the umbo correspond? Evidences?

243. **The Organs of Special Sense.**—Experiments show that the mollusks are sensitive to the usual external stimuli. Sensory cells are scattered over the epithelium of all the exposed surfaces. These give a sense of touch and of the chemical conditions. The edge of the mantle and the tentacles are always especially sensitive. In addition to these are special patches of cells, in many forms, believed to have a smell or taste function. Sac-like cavities, lined with sensory cells and containing a fluid in which are solid particles (*otocysts*), are found. These have long been believed to be organs

FIG. 70.—Diagram of the nervous system of the clam—from the dorsal aspect. *a*, anterior; *o*, mouth; *c.g.*, cerebral (brain) ganglia; *p.g.*, pedal ganglia; *v.g.*, visceral ganglia.

Questions on the Figure.—Find, in the reference texts, a figure showing the nervous system of the clam from the side view. What is the function of each of these ganglia? Compare with figures of other mollusks.

to perceive vibrations in the medium in which the animal lives, probably sound vibrations; but recent investigations incline us to believe that these structures are rather gravity organs to determine the position of the animal in the water.

Eyes are usually present, though they vary much in efficiency. Fig. 71 gives a series of such eyes, taken largely from the mollusks. The cephalopods have very complex and highly developed eyes, much like those of vertebrates. In the lamellibranchs the eyes, when present, are on the edges of the mantle; in the other types they are about the head.

244. Reproduction and Development.—The reproduction is always sexual, though the sexes are often in the same individual (as in the oyster, and many of the gasteropods). The eggs, after being fertilized, are laid singly or in masses, often surrounded by gelatinous secretion (as in the snails) which serves as a means of protection from drouth, and for attachment. In cephalopods the eggs are

FIG. 71.—Diagram showing various types of invertebrate eyes. B, C, and D show conditions in various mollusks. Eyespots similar to A and E are found in certain jelly-fish. *ep*, epidermis; *f*, nerve fibre; *l*, lens; *op*, optic nerve; *p*, pigment cells; *r*, retina; *vh.*, vitreous humor. F shows a few cells of retina much enlarged.

Questions on the Figure.—Begin with A and describe the progressive changes that take place in this set of figures. Discuss the possible value of each change. In what way would B be a better eye than A? What two elements are shown in the retina? What is the function of pigment?

large and contain a large amount of nourishment. The cephalopods and the land snails do not undergo a metamorphosis. The other types pass through larval stages similar in some respects to those of the marine worms (*trochosphere*). In the clam the larva is parasitic during a part of its life.

245. Relation to Nature.—The mollusks have been a most successful group of animals from the first geological

records of life. They ruled the early seas. They have always been numerous both in species and individuals. They occupy the ocean at all depths, the fresh waters, and the land. They devour, and in turn furnish food for, many other forms. They have their share of parasites; there are boring snails that rasp through the shell

FIG. 72.—*Mya arenaria*, a burrowing clam. The siphon is represented as fully extended. This is quickly retracted when the animal is disturbed.

Questions on the Figure.—Why the much elongated siphon? Find other figures of syphons and compare. Which is the anterior end of the animal? What seems to be the chief function of the foot in this case?

and attack the soft parts of other mollusks; starfish are the greatest enemy of the oyster, and probably of other attached or slow moving kinds; fishes, frogs, and birds all help in their destruction.

The shell of course is a means of protection against these enemies. These shells may be colored on the outside in such a way as to be inconspicuous, or minute growths of various kinds may cover them in such a way as to secure the same end. A good many of the lamelli-branches become attached or fixed in one way or another. The poor development of the nervous system and the general appearance of degeneracy, as compared with the other mollusks, is doubtless correlated with this fact. Some bore into wood or even stone when they first settle down, and burrow out a chamber in the solid object, which increases as they grow in such a way that they cannot get out through the opening. Find figures of the ship-worm (*Teredo*) or of *Pholas* or some other rock-boring type. The long-necked clam burrows in the sand (Fig. 72). The burrowing forms have the *siphon*, a special tubular growth of the mantle, through which they reach out into the water and get their supplies. The oyster attaches itself permanently to the rocky bottom by one valve.

The cephalopods find safety in their splendid powers of swimming and in their ability to fight.

246. Relation to Human Interest.—This is the first group that we have studied that has any value, worthy of mention, as a food to man. The oyster industry is a matter of considerable magnitude, though the actual food contained in oysters is slight. It is estimated that about ten million bushels of oysters are marketed annu-

ally in this country. The only way in which this can be increased is by scientific "farming." This implies the proper preparation of suitable shallows, and the planting of the young oysters there, and the protection of them from their enemies, including man, until they reach maturity, which is for about five years. This is made possible by the great power of multiplication which the oyster has. It is claimed that a single oyster may produce 60,000,000 eggs.

Other forms that have been used more or less as food are the fresh-water mussel, the long-necked clam, and several species of marine mussels. Large species of snails are prized as food in some regions.

Most mollusks secrete a pearly substance at some part of the mantle. This is normally spread out thinly over the inside of the shell and is called "mother-of-pearl." Pearl buttons, knife handles, and the like, are made from the shells of our fresh-water clams. This is quite an industry on some of the tributaries of the Mississippi.

In a few species, under certain abnormal conditions of irritation of the mantle, possibly due either to disease or to the presence of some irritating substance next the mantle, there is the formation of the pearl in a massive form. These are concentric layers of mother-of-pearl. Pearls have long been much prized as ornaments. They have been found in great quantities in some of the graves of the mound-builders. The finest pearls come from the marine pearl oyster (*Meleagrina margaritifera*), though good ones are found frequently enough in our fresh-water forms to add interest to the search. Small ones are frequently found in the common oyster. Squid are used as bait by fishermen. Some of the boring forms do much damage to piles and other subterranean timbers placed

in the ocean by man. Snails sometimes attack foliage in such numbers as to work injury.

A large portion of the limestone of the earth's crust has been extracted by these animals from its solution in sea-water and deposited at the bottom, when they die,

FIG. 73.—*Pecten irradians*,—a scallop. From Binney's Gould.

Questions on the Figure.—Is this an internal or an external view? Where is the umbo? What is peculiar about the hinge in this case? What is the significance of the lines nearly concentric with the margin? Of the radial lines?

as solid shells. Here it is cemented together by the action of the water and finally compressed into the familiar and useful stone.

It is believed that the oyster is a frequent spreader of certain germ diseases, as typhoid fever, owing to the fact that many of the oyster fisheries are located on inlets of the sea into which the sewage from great cities passes.

The germs either enter the body of the oyster in its food, or may be merely attached to the outside and in the liquor of the animals. The danger is greater because oysters are eaten raw or only slightly cooked.

FIG. 74.—*Helix*. A, an empty shell, in section from apex to base. *a*, apex; *an*, anus; *ap*, aperture of shell; *c*, columella or axis; *e*, eyestalk; *f*, foot; *l*, lip of shell; *m*, edge of mantle, which secretes the shell; *r.o.*, respiratory opening; *s*, suture or groove on shell; *t*, tentacles. B, shows the relation of the snail to the shell when extended.

Questions on the Figure.—What suggestions of bilateral symmetry are shown by the snail? Where does growth occur in the shell? What are the functions of the tentacles? Does the snail inhabit the shell clear to the apex?

247. Definition of the Mollusca.—The mollusks agree in having soft unsegmented bodies, a portion of which—the mantle—usually secretes a protecting shell. The chamber between the mantle and the body contains the respiratory organs. There are no segmented paired appendages, though there is a muscular modification of the body wall which is spoken of as a foot.

248. Classification of Mollusca.

No head; gills leaf-like; bivalve shell. . . . *Class Lamellibranchiata*.

Two equal adductor muscles. . . . *Order Isomya*.

Examples: Mya (marine clam); *Teredo* (the ship-worm).

Fresh-water mussels; *Cardium* (cockles).

Anterior adductor muscle smaller. Order Heteromya.

Examples: Modiola (horse mussel); *Mytilus*; *Meleagrina* (the pearl oyster).

One adductor muscle. Order Monomya.

Examples: Ostrea (oyster); *Pecten* (the scallop; Fig. 73).

Head well developed; shell when present univalved.

Foot developed into a ventral crawling disc,

Class Gasteropoda.

FIG. 75.—*Helix albolabris*, a pulmonate Gasteropod. Binney's Gould.

Questions on the Figure.—What is the meaning of *Helix*? of *albolabris*? Identify the parts of the shell (see Fig. 74). Is it a right or left spiral? Just what do you mean by your answer?

FIG. 76.—*Limax flavus*, a slug. From Binney's Gould.

Questions on the Figure.—How do the slugs differ from the other gasteropods? In what external respects do they seem similar to them? Compare all the figures of slugs you can find.

Lungs; land or fresh-water habitat. Order Pulmonata.

Land snails.

Shell; four tentacles. Family Helicidæ.

Example: Helix, Figs. 74 and 75 (with 3,000 species).

No external shell. Family Limacidæ.

Examples: Limax (the slugs, Fig. 76).

- Pond snails.....(chiefly) Family Limneidæ.
 Sharp; right-handed spiral.....Genus *Limnea*.
 Sharp; left-handed spiral.....Genus *Physa*.
 Flat coil (like watch spring).....Genus *Planorbis*.

Gills; marine.

Gills in front of heart; operculum present,

Order Prosobranchiata.

Gills behind heart; no operculum. Order Opisthobranchiata.

Foot modified into tentacles about the mouth,

Class *Cephalopoda*.

FIG. 77.—*Pearly Nautilus*. From Nicholson. *e*, eye; *h*, hood, a muscular portion of foot which protects the softer parts; *s*, siphon; *se*, septa, separating the successive chambers of the shell; *sp*, siphuncle; *t*, tentacles—divisions of the foot.

Questions on the Text.—How does the shell compare with those of gasteropods? Why are the tentacles (arms) thought to be homologous with the foot of the snail? What is the siphuncle? What is the character of the eye in *Nautilus*?

Four gills; many-chambered shell.....Tetrabranchiata.

Example: Chambered-*Nautilus* (Fig. 77).

Two gills.

Ten tentacles.....Order Decapoda.

Examples: Cuttle-fish; squid.

Eight tentacles.....Order Octapoda.

Examples: *Octopus* (devil-fish, Fig. 78); Paper *Nautilus*.

249. **Topics for Themes in Zoology and English.**—1. Can you show any relation among mollusks between the presence of external protective structures and the degree of activity?

2. What grounds are there for believing that the lamellibranchs are degenerate mollusks?

FIG. 78.—The Devil-fish (*Octopus*). From Cooke. A, at rest; B, swimming. *a*, arms, with suckers on the inner side; *e*, eye; *s*, siphon or funnel.

Questions on the Figure.—Which is the anterior end of the animal? What is the position of the mouth? What is the function of the siphon? Of what structure is it a part? Compare the devil-fish with the squid, through figures.

3. In what ways may the land snails have arisen from the original marine forms?

4. Write a more extended account of the economic value of mollusks.

5. Write an account of “oyster farming” and the conditions that are favorable for it. How does the oyster of our Atlantic coast compare with other oysters?

6. What is the nature and what the source of the following: Sepia? Cuttle-fish bone? Tyrian dye?
7. Write of the pearl industry. Location and methods.
8. The manufacture of pearl buttons.
9. The color of shells in mollusks. Location.
10. A report on all the mollusks found in your locality; their habits, distribution, etc.
11. Some special spring studies on the habits and behavior of some members of this group.

CHAPTER XX.

PHYLUM XI: ARTHROPODA.

250. **General Survey.**—The crayfish and grasshopper belong to this group, and illustrate two of the four principal divisions. The crayfish belongs to the Crustacea, and the grasshopper to the Insecta. In addition to these are the Arachnida or spiders, and the Myriapoda which includes centipeds and other types with legs along the entire body.

The branch of arthropods embraces more than half the species in the animal kingdom and many of these species are very rich in individuals. They agree with annelids in having a bilaterally symmetrical body made up of segments, and a nervous system of numerous ganglia on the ventral surface. The larvæ (grubs and caterpillars) are much like worms in appearance. They differ from worms in the fact that the paired appendages which spring from these segments are *jointed*. The epidermis of the arthropods secretes a horn-like substance, which in some cases becomes very thick and resistant, making an external skeleton for protection and the attachment of muscles. If this skeleton remains thin at the joints the animal is flexible; if not, the segments may be fused in such a way as to become quite rigid, as in the crabs. In some cases they are fused in the anterior part of the body and flexible elsewhere.

The great number of species referred to above points to the fact that the arthropods are able to adjust them-

selves successfully to many different kinds of life. None of the phyla are more cosmopolitan than this. They may be internal or external parasites, symbiotic, social, or independent; they live in water, on the land, burrow in the soil and in other substances as wood and fruits, and fly through the air; they use all possible kinds of foods; they

FIG. 79.—Diagrammatic cross section of crayfish in the thoracic region, to show relation of circulation and respiration. *a*, appendage; *c*, carapace; *c.f.*, flap of the carapace overhanging the gills; *d*, digestive tube; *g*, gill; *h*, heart; *l*, liver; *m*, body muscles; *m'*, muscles of the appendages; *n.c.*, nerve cord; *ps*, pericardial sinus; *r*, reproductive organs; *st*, sternal artery; *v.a.*, ventral artery; *v.s.*, ventral blood sinus in which the nerve cord lies. After Lang.

Questions on the Figure.—What is the relation of the gills to the body wall? Follow the course of the circulation by the arrows. It leaves the heart by definite arteries and comes back by less definite blood sinuses. What is the function of the valves? What gain is there in the position of the ventral nerve cord in the blood sinus? What is the value of the overarching carapace (*c.f.*)? What is the position of the water, in the figure? How is it renewed? See texts.

bore, crawl, jump, swim, fly, or may be fixed. The group must be considered as one of the most successful in the animal kingdom. None of the individuals, however, become very large. The lobster and some of the crabs are among the largest. Many are microscopic. The forms that are parasitic are degenerate, and lose many of the characteristics that the independent species have.

The features that make them especially attractive for study by elementary students are their great variety, the range of their habits and instincts, the beautiful coloration of so many species, the interesting metamorphosis through which so many of them go before they become adult, and the great importance they have to human interests, both beneficial and injurious.

251. How many species of this branch did you find on your collecting tours? What percentage of all the species you found were of the branch of arthropods? Did you find representatives of each of the four main subdivisions? How many different modes of life did you find represented among them?

252. **Field Work on Spiders: a Practical Exercise.**—After examining several spiders, state how you may always be able to distinguish a spider from an insect by a study of the exterior? After a period of study in the field, let the students report on the haunts and place of life of as many kinds of spiders as have been found. Do any live under boards and stones? Do any burrow? Do all kinds spin webs? How many different kinds of webs are you able to discover? Are they equally regular and complex? Determine by observation, if possible, to what various uses the web is put by different species of spiders? Learn to recognize the spider which produces

the different type of web. How is the web produced? Details of the construction, and the order in which the parts are made (Fig. 100).

Select some well-developed web and watch the behavior of the spider in reference to it. What is the usual position of the spider? How does he behave when an insect becomes entangled in it? Study carefully; record all your observations; indicate your conclusions as to the senses on which the spider most depends in capturing his prey. Do spiders develop directly or do they have a metamorphosis? Are "Daddy-long-legs" spiders or insects? Mites and ticks belong to which division? Study figures in text-books.

253. **"Thousand-legs:" a Practical Exercise.**—These are elongated, weak-bodied creatures, which every student has seen under boards and stones, or in other moist places. The body may be flat, or rounded, in cross-section. Each segment of the body may have one (or two) pair of appendages.

In how many different kinds of places have you found them? Can you get any clue to their feeding habits? What is their behavior on being exposed and touched? How many segments in the body? How much variety among the segments? How many pairs of appendages? Are these all alike? Are they *homologous*? How many different functions do you think these appendages may perform? Evidences?

Study the method of locomotion. In what way are the numerous appendages used? Do all on one side act at one time? If not, how do they act?

What senses have the myriapods? Do these seem more or less like annelids than the insects do?

254. **The Relatives of the Crayfish (Crustacea).**—In this division belong the lobsters (Fig. 81), crabs, shrimps, barnacles, water-fleas, and sow-bugs. The most of them are marine; but the crayfish and a number of species of much smaller types live in fresh water, and the sow-bug and pill-bug are air-breathing. They have a thicker covering than spiders and insects, as a rule.

The lobsters are quite similar to the crayfish in everything except size. They are marine and are found along

FIG. 80.—Larva of lobster (*Homarus americanus*) removed from egg shell. From Herrick.

Questions on the Figure.—Compare with the adult (Fig. 81) and note similarities and differences. Examine Dr. Herrick's figures (Bull. U. S. Fish Commission for 1895), and notice the gradual change to the adult condition by successive moultings. What structures can you identify?

all our coasts. They feed upon various slow-moving invertebrates and upon dead fish. It is claimed that they are able to capture living fish also. They are often colored in such a way as to harmonize with their surroundings and this aids in the capture of their prey. The lobsters stand next in importance to the oyster as an invertebrate food-species for man. It has been captured in such numbers during the last twenty years that it is in danger

of extinction as a food animal. Measures are now being taken to protect the adults from overfishing and to hatch the young in protected places; and it is hoped that the

FIG. 81.—The adult American lobster (*Homarus americanus*). Herrick.

Questions on the Figure.—What body regions are to be distinguished in the lobster? Compare by actual measurement the size of the crushing claw compared with that of the body. How many segments in the abdominal region? Compare the lobster with the crab (Fig. 84).

lobster fisheries may thus be restored to their earlier fruitfulness.

The hermit-crab (Fig. 85) is peculiar in that it backs into an empty gasteropod shell, and uses this as a protection to the posterior part of its body. In consequence this part remains soft and becomes degenerate, while the anterior appendages, which extend from the mouth of the shell and are used in the capture of food, have a hard skeleton.

FIG. 82.

FIG. 82.—The Zoëa of *Cancer irroratus*. From Verrill. $\times 7$.

FIG. 83.

FIG. 83.—Megalops of *Cancer irroratus*. From Verrill. $\times 7$.

Questions on Figures 82 and 83.—Compare these two stages of the development of the crab and note the chief changes. Compare also with the adult crab, and write a statement expressing some of the chief changes in its development. Compare both these larvæ with that of the lobster (Fig. 80). What are the differences between the development of the lobster and the crab. Is the larval crab or the adult crab more like the lobster? What inference would you deduce from this fact?

255. The Crabs.—The short-tailed crabs are broader and shorter than the lobsters, and have their much reduced abdominal segments turned under the thorax. These are the highest crustacea, and in their development pass through stages somewhat like the adult of the long-tailed crustacea (Figs. 82 and 83). They are very varied in

appearance, although they are alike in fundamental structure. The largest of the crustacea is the giant crab of Japan whose spider-like legs are said to reach 18 or 20 feet from tip to tip.

256. **Barnacles.**—The barnacles are attached in their adult stage, although they are free-swimming in the embryo. They develop strong, limy plates which suggest

FIG. 84.—Violet land crab. Adult. After Shufeldt.

Questions on the Figure.—Compare this with all the figures of crabs available, and note the points at which the chief variations occur. Compare crabs and lobsters with respect to body regions, segmentation, and appendages.

the shell of the mollusk, and for this reason they were long classed as such. Their manner of development and the structure of the appendages show, however, that they are degenerate crustacea. They attach themselves to the rocks and piles from a point above low tide to considerable depths. Floating objects are sure to become covered with them. The hulls of ships may become foul with them during long voyages.

FIG. 85.—Hermit crab, in the shell of a Gasteropod. Morse.

Questions on the Figure.—What structural adaptations has the hermit crab to this mode of life? What changes have come as the result of the mode of life? What conceivable gain has such a habit? What animals are cited as symbiotic with the hermit crab?

FIG. 86.—*Palæmonetes vulgaris*. From Verrill.

Questions on the Figure.—Compare the appendages of *Palæmonetes* with those of the lobster, the crab, and *Gammarus*. What seem to be the functions of the various appendages, so far as position and form may indicate?

257. **The Smaller Crustaceans.**—Less conspicuous and less highly developed than these are many species, including a number of fresh-water forms—the “water-fleas.” If the student makes any study of stagnant waters he is sure to find these minute crustacea darting about the side of the vessels in the laboratory. The most common type is *Cyclops*, named from the single eye in the middle line of the head. *Daphnia* is another beautifully transparent form that is

FIG. 87.—*Gammarus ornatus*. From Verrill.

Questions on the Figure.—How does this form compare with other crustacea studied—in the differentiation of the segments, in fusion of the segments, and in the differentiation of the appendages?

FIG. 88.—*Caprella geometrica*. From Verrill. $\times 4$.

Question on the Figure.—In comparison with other crustacea, what are the aberrant or peculiar features of this form? See also figures in reference texts (e. g., Parker and Haswell's Zoology, Vol. I, p. 546).

very common. They both multiply very rapidly and keep close up to the limits of the supply of the food on which they live. It is said that one adult cyclops may in the course of a season produce 500 young, and since each of these becomes sexually mature in a short period, it is estimated that the descendents of one cyclops, if everything were favorable for their living, would amount to 4,500,000,000 individuals in a season. Of course this never happens in

reality, for these animals are a chief source of food for fishes and other water animals.

There are many marine crustacea related to cyclops. Many of them are parasitic, infesting the skin, gills, the intestine, and other organs of the larger invertebrates, the fishes and whales.

258. The Relatives of the Grasshopper (Insecta).—This division of arthropods is in contrast with the Crustacea in the fact that the insects are chiefly air-breathing. The insects have typically four pairs of jointed appendages in the head (one pair of antennæ and three pairs of

FIG. 89.—*Sminthurus hortensis*—a spring-tail. $\times 35$. From Folsom's Entomology.

Questions on the Figure.—Consult other texts and discover the habits and special adaptations of these insects.

mouth parts), and three pairs of legs on the thorax. The name *Hexapoda* is sometimes given them because of this regularity in the number of legs. There are more species of insects than of all the rest of the animal kingdom put together. Included here are the wingless spring-tails, the fleas, the May-flies, the dragon-flies, the cricket, the katydid, the cockroaches, lice, plant-lice, bugs, beetles, flies, gnats, mosquitoes, butterflies, moths, ants, bees, and wasps. All the grubs, caterpillars, maggots, and the like, are larvæ of this division.

259. Wingless Insects.—While most insects have wings, there are some groups which do not. Among these are

the spring-tails and snow-fleas (Fig. 89). Probably these have never had wings. There are some other wingless types which are related to forms that have wings. Such are some of the workers among the ants, many plant lice, certain scale insects, walking-stick, fleas, and other parasitic forms. It is believed that these have lost their wings through gradual adjustment to their special methods of life.

FIG. 90.—Katydid (*Cyrtophyllus perspicillatus*), natural size. Photo by Folsom.

Questions on the Figure.—How many pairs of appendages are visible in the figure? How many are really present? To what order of insects does the katydid belong? What are its feeding habits? What can you find of its development? Does it have a metamorphosis?

260. **The Orthoptera (Grasshoppers, Crickets, Katydid, and Cockroaches).**—These may be taken as illustrative of the less complex and less highly developed insects. They commonly have four wings, the anterior pair being somewhat hardened and the posterior folding up lengthwise beneath these when at rest. Their mouth parts are adapted to biting and they are voracious eaters. The crickets, katydids, and cockroaches (Fig. 90) are nocturnal

in their habits. When the young are hatched they are much like the adult. They grow and undergo the slight changes necessary, by a series of moults in which the hard outer shell is shed. The soft parts then grow before the new shell hardens.

This order is of considerable economic importance. The locusts are active feeders, multiply abundantly, and often move in great swarms in search of food. In this way the Rocky Mountain locust swept down from its breeding places over the plains of Nebraska and Kansas in 1873 and again in 1878, stripping the fields of vegetation.

261. **The Diptera (House-flies, Horse-flies, Mosquitoes, Gnats, etc.)** (Fig. 91).—This group has only one pair of wings (whence the name), and the mouth parts are adapted to piercing and sucking instead of biting. There are a great many species in this order and they have extraordinary powers of reproduction. The eggs are laid and the larvæ develop in connection with decaying organic matter, as flesh, fruit, manure, stagnant water, and the like. The larvæ of flies are known as maggots; those of mosquitoes and gnats are the “wiggletails” of the rain barrel or the pond. These animals do their growing in the larval stage and pass into the mature stage full grown. The members of this group are very important to man. While the larvæ are scavengers and consume decaying matter, the adults are unquestionably among the worst carriers of disease known to us. The work of the mosquito in this respect has already been referred to (p. 160). The common house-fly is probably as great an offender in spreading typhoid and other similar intestinal diseases, by carrying the germs and

depositing them on food in crawling over it. Mankind will undoubtedly wage a war of extermination on both flies and mosquitoes during the next generation.

FIG. 91.—Stages in the development of the botfly (*Gastrophilus equi*). See also Fig. 33. After Brehm. *a*, adult insect; *b*, egg attached to a hair; *c*, *d*, and *e*, stages in the development of the larva.

Questions on the Figure.—Review the habits of this fly. What are the special adaptations—structures and instincts—that fit it for its mode of life?

262. The Coleoptera (Beetles).—This is probably the largest group of the insects. There are said to be 100,000 known species. The beetles are easily recognized by the fact that the front pair of wings are hardened and serve as covers for the real wings. The mouth parts are well

adapted to biting and they undergo a complete metamorphosis. The larvæ are often known as "grubs." A few beetles prey upon hurtful insects. For example, the lady-bug beetle devours great numbers of the scale insects, which are proving such a pest to orchards of various kinds. More commonly, however, they are vegetable feeders, and there is no form of vegetation

FIG. 92.—The hessian fly (*Cecidiomya destructor*). From Standard Natural History. a, adult; b, larva; c, pupa; d, larva in position on stalk of wheat.

Questions on the Figure.—Give names to all the structures apparent in the adult. In what stage does the insect do its damage? What is its economic importance? What is the origin of the common name?

which is not attacked by them. The potato-beetle devours the leaves of the potato plant; the curculio, and other forms, lay their eggs in fruits, such as plums, apples, peaches, and the like, and the grub burrows about getting its living as the fruit ripens; the cotton-boll weevil bores into the young cotton fruit and injures or destroys the growing fibers, robbing the cultivator of millions of dollars annually; many of the weevils attack

stored grains of various kinds; numerous beetles lay their eggs in wood, dead or living, and their larvæ eat their way in tunnels through the solid timber. It sometimes takes these larvæ four or five years to mature, and thus they are able, in getting their nutrition, to do a great amount of damage. With these are to be included the fire-flies, the scarabs or dung beetles, the June bugs, and some water beetles which may be seen whirling about at the surface of ponds or diving beneath it.

Many of the beetles are brilliantly colored, and for this reason are often collected by young students. It is thought that these colors may, in some instances at least, be of direct value to the animals.

FIG. 93.—The army-worm (*Leucania unipuncta*). After Riley. A, caterpillar; B, adult moth.

Questions on the Figure.—What are the principal facts concerning the habits and economic importance of the army-worm? Why is it so called?

263. The Lepidoptera (Butterflies and Moths).—These are the most conspicuous and best known of the insects. They are found all over the world and are so various in size, color, and habits as to be one of the most interesting groups of animals for popular study. The mouth parts are elongated into a proboscis for sucking the nectar of flowers. They pass through a complete metamorphosis,

the larvæ being known as caterpillars. There are two pairs of wings and these are covered with minute scales that fall away as a powder when the insects are handled.

FIG. 94.—Swallow-tail butterfly (*Papilio machaon*)— larva, pupa, and adult.
From Nicholson.

Questions on the Figure.—Which is the larva and which the pupa? Which of these is the earlier stage? What are the chief characteristics of the three stages in the metamorphosis of butterflies—the larva, the pupa, and the imago?

The butterflies are more slender of body and more highly colored, as a rule, than the moths. Moreover, the butterflies fly by day and the moths chiefly by night; the pupa of the moth is often surrounded by a cocoon, while that of the

butterfly is not; when at rest the butterfly holds its wings upright, and the moth's wings droop to the support. The

FIG. 95.—The cabbage worm (*Pieris rapæ*). Natural size. Photo by Folsom.
A and B, larvæ; c, pupa.

FIG. 96.—The adult cabbage butterfly (*Pieris rapæ*). Natural size. Photo by Folsom.

Questions on Figures 95 and 96.—What is the color of this caterpillar in nature? What are its feeding habits? Why is the adult called a “cabbage butterfly”?

antennæ of the butterfly usually has a club on the end, while those of the moth do not.

In the adult form the moths and butterflies do no harm, except to lay their eggs. Indeed, they are of considerable

service. They carry the pollen from flower to flower in their search for nectar, and thus bring about the cross-fertilization which is apparently so valuable to plants (Fig. 28). It is in the caterpillar stage that they are most injurious to human interests. The caterpillars, often known as "worms," are voracious feeders and eat leaves of all sorts, fruits, seeds, and the like (Figs. 93-95). One form, the larva of the clothes moth, lives on animal matter, such as furs, woolens, and hair. The silkworm, which lives largely on the mulberry leaves, is the most useful member of the order..

264. **The Hymenoptera (Ants, Bees, and Wasps).**—This seems the most highly developed division of the insects; at least they have impressed man, as no other insects have, with their marvelous instincts in care of young, in making homes, in storing food, and in organizing into social communities. They have two pairs of membranous wings; they undergo a complete metamorphosis, the larvæ being white grubs; and their mouth parts may be formed either for biting or for sucking or for both at once.

Not all of the members of this group are social. There are stages extending all the way from wholly independent life, as in the solitary wasps and the carpenter bees, up to the complex social life of the honey bees and the ants. This social life and the making of homes centers about the laying of eggs and the rearing of young. It may also imply the laying up of food for winter use, but this is not always true. These homes may be borings in the ground or in wood; they may be manufactured entirely by the animal of mud (dirt-daubers), or of wood pulp spread out in the form of a paper (as the hornets), or of

wax made by internal processes (as in the honey bees). In these homes the young may be actively fed (as by the ants), or the eggs may be laid directly in the secreted food (as in the honey bee), or may be deposited in a cell together with insects that have been stung and partly paralyzed, on which the larva feeds (as in the case of the solitary wasps); or they may be laid in the growing parts of plants, where they form a gall and live on the juices of the plant that are drawn to this actively growing structure. A few types (ichneumon flies) lay their eggs in the body of caterpillars where they develop and become truly parasitic during the larval stage. They escape after pupation and live their adult life independently.

In the more complex colonies, such as those formed by the honey bee and the ants, there are usually at least three kinds of individuals. These include queens or sexually perfect females who lay the eggs; males, often drones; and workers, which are usually females that are not sexually complete. In the ants the workers may be differentiated into several types to whom different kinds of work are intrusted. In addition to this some of the ants have formed the habit of capturing the larvæ of other species of ants and rearing them as the slaves of the colony. Aphides or plant-lice are held in a similar way by some ants for the sweet secretion which they produce.

265. Less Important Orders of Insects.—There are a number of other orders of insects of which the student will find interesting illustrations, although the order as a whole is less important than those we have mentioned. Among these is a group to which the beautiful dragon-flies belong (Neuroptera). Related to these are the "white ants" and the May-flies.

The order Hemiptera (true bugs) include some of the worst pests among the insects. Here are the plant-lice (aphides), the squash

bug, the scale insects, the destructive chinch bug. Related to these are the Cicadas (the 17-year locust, Fig. 97) and various water bugs (as the water-boatman and back-swimmers). For further details of these groups the student should refer to some special work on entomology.

266. The Spiders and their Relatives (Arachnida).—These animals have two pairs of head appendages and four pairs of legs. The head and thorax are more com-

FIG. 97.—Periodical *cicada*. Natural size. Photo by Folsom.

Questions on the Figure.—To what order of insect does the *cicada* belong? Which of its habits are most familiar to you? What are its nearest relatives among the insects? How long does it take to mature?

pletely fused than in the insects (Fig. 99). They do not have antennæ. Most of them are air-breathers, although some of them live on or under the water. They do not have the compound eyes that are so common among the arthropods. Most of them prey upon insects and are thus of advantage to mankind. They do not pass through a metamorphosis.

With the spiders proper are classed the scorpions (Fig. 98), the daddy-long-legs or harvest-men, the ticks, and the mites. The ticks and mites are external parasites on mammals and birds. Some mites are parasitic on

plants. The cattle-tick of the South is the means of spreading the cattle disease known as Texas fever. The mange among live stock, and itch in man are caused by parasites belonging to this group.

FIG. 98.—Scorpion (*Buthus*). Photo by Folsom.

Questions on the Figure.—Compare the scorpion with figures of crustacea, insects, and spiders, noting the chief differences and likenesses. Of what use is the long, segmented abdomen in the scorpion? What are the nearest kin of the scorpion?

Limulus, the king-crab or horse-shoe crab, is classed by some zoologists near the spiders. In external appearance it is more like the crabs, but its internal anatomy and its development suggest its classification with the arachnida.

FIG. 99.—Spiders (*Epeira marmorea*). After McCook. Male on left; female on right. Natural size.

Questions on the Figure.—What differences do you note with respect to the sexes? What habits of the spiders are correlated with this difference in size in the sexes?

FIG. 100.—Web of *Epeira strix*, an orb-weaving spider. After McCook.

Questions on the Figure.—By reference to other texts or by observation determine if there is any regular order in which the parts of the web are produced. To what is this kind of web an adaptation? Evidences? What other forms of web are made for similar purposes?

267. The Thousand-legged Worms (Myriapoda).—

These are the lowest and simplest of the four classes of arthropods. This is shown by the lack of differentiation among the segments which suggests the segmented worms and the larval stages of the insects. One division (the *centipeds* (Fig. 101) are carnivorous and live on worms and insects. A few of this group living in tropical regions

FIG. 101.—Centipede (*Scolopendra heros*). Photo by Folsom. Four-fifths natural size.

Questions on the Figure.—What differentiation of segments is apparent? Are there any fusions of segments into body regions? What is the law of the occurrence of appendages? What diversity is there among them? In what respects does this animal seem intermediate between the annelids and the higher arthropods?

are poisonous. The common ones are entirely harmless to men, and the hurtfulness of the poisonous ones is much exaggerated. The animals of the second division (*millipeds*) have two pairs of legs on each segment. They are vegetable feeders, have elongated rounded bodies, and tend to roll up in a coil when disturbed.

268. A Contrast of the Four Types of Arthropods: A Library Exercise.—Select a good representative of each of the four types of arthropods: myriapod, crustacean, arachnid, and insect. By means of parallel columns write a comparison of them in respect to the following facts:

Topics	Myriapod (e.g., <i>Lithobius</i>)	Crustacean (e.g., crab)	Arachnid (e.g., some large spider)	Insect (e.g., wasp, or butterfly)
1. Regions of the body.				
2. Number of segments and their freedom, or fusion.				
3. Differentiation of segments.				
4. Number, character, and diversity of appendages.				
5. Eyes.				
6. Manner of respiration.				
7. Kind of food used and its capture.				
8. Place of laying eggs, number, etc.				
9. Manner of caring for the young.				
10. Manner of development.				

269. **Comparative Study of Insects: a Practical Exercise for Library and Field.**—Make a table similar to that on the preceding page, for a representative of each of the principal groups of insects. Include in it the principal points of similarity and contrast that you can discover.

FIG. 102.—Mouth parts of a cockroach (biting). A, upper lip (*labrum*); B, mandibles or jaws proper; C, hypopharynx; D, maxillæ, or under jaws; E, under lip or labium. From Folsom.

Questions on the Figure.—By study of other texts determine the function of these various structures. Compare with the next figure.

The following will be good animals although others just as good may be found by the student: the grasshopper; the June-bug or other beetle; a dragon-fly; a water-boatman; the cicada or the squash bug; a butterfly; a fly or mosquito; a bumble bee; an ant. Among other things, the following points should be worked out:

1. The three main regions of the body and the degree of their development.
2. The antennæ and mouth parts, and the kind of work they are adapted to (Figs. 102 and 103).

FIG. 103.—Mouth parts of a female mosquito. A, dorsal view; B, transverse section. *a*, antenna; *e*, compound eye; *h*, hypopharynx; *l*, labrum; *li*, labium; *m*, mandible; *mx*, maxilla. C, end of maxilla enlarged; D, end of *l*, enlarged. After Dimmock, from Folsom.

Questions on the Figure.—What are these mouth parts adapted to do? Study the cross section in determining something of the function of each part. Compare these parts with the corresponding parts in the cockroach and enumerate the differences.

3. The degree of development of the three pairs, of legs and the way they are used.
4. The number, size, structure, and position of the wings, with a comparison of the first and second pairs.

5. The abdomen, its degree of development, its segments, and its appendages.
6. The eyes, simple and compound.
7. Their haunts and special place of living.
8. Methods and efficiency of locomotion.
9. Material used for food in both larval and adult stage and the mode of getting it.
10. The organs of respiration and their location.
11. The special senses.
12. The laying of eggs and provision for the young.
13. The degree to which they make homes, and the manner of their construction.
14. The life history.
15. The difference between the sexes.
16. The degree to which they associate in social life.
17. Means of defense against enemies.
18. The most conspicuous devices either of structure or instinct that would help to adapt the animal to the conditions of its life.

[If the available time is short, this exercise may be divided among the members of the class.]

270. Organs of Special Sense Among the Arthropods.—Because of the cuticle that covers the body in arthropods, the sensitiveness of the skin cannot be so great as in naked forms. To compensate for this there are numerous special hairs of the same material as the cuticle, which are supplied with nerves from below in such a way as to connect the sensory parts of the organism with the outside conditions. These hairs are usually more abundant on the movable parts, especially those about the head. They may be organs of touch, and, in the case of the male mosquito (Fig. 104), they are believed to be hearing organs. There are several different kinds of organs among arthropods

which have been considered to be for the purpose of hearing. It is believed that the hearing is best developed in those air-living forms in which definite noises are made, as in the crickets, katydids, cicadas, and the like.

The most remarkable organ of sense in the group is the

FIG. 104.—Antenna of male mosquito (*Culex pipiens*). By J. W. Folsom.

Questions on the Figure.—Compare with the antennæ of the female (See Fig. 103). What are the differences between the head and its appendages in the male and female mosquito? What is believed to be the function of the male antennæ? Evidences for this view?

compound eye, which is found both in the crustacea and the insects. There are often, in addition, simple eyes (*ocelli*). The general structure of the compound eye is suggested by Fig. 105, but the student must be referred to more advanced texts for the details of its structure and use.

271. **Reproduction.**—In addition to the common method of sexual reproduction, many types of insects have the power to lay eggs, which will develop without being fertilized. This is known as *parthenogenesis*. It is found in the plant-lice, in the scale insects, among some Diptera

FIG. 105.—Diagram illustrating the compound eye in arthropods. A, whole eye shown in section; B, one of the eye elements more highly magnified. *c*, cuticular facets on outside; *ep*, epidermis; *l*, group of cells forming a lens-like body; *n*, optic nerve fibres; *o*, optic ganglia; *p*, pigment cells.

Questions on the Figure.—In what way is each *ommatidium* (eye element) made independent of the others? In other words, what is to prevent light from passing obliquely from one to another? In what way is a general image probably formed by means of these numerous eyes? Do all the arthropods have these compound eyes? How do the ocelli (simple eyes) compare with these? Find figures.

and Lepidoptera, in many of the social insects, as wasps and bees, and in some of the lower crustacea. It is often true that the individuals resulting from unfertilized eggs are different from those coming from the fertilized.

The males and females usually differ considerably in color and size. The females are usually the larger and the males more highly colored.

272. **Development.**—Some of the arthropods hatch at once into the adult form, but the metamorphosis is much more common. The egg has considerable food to start with, and it is usually laid in positions where the young can get food as soon as it is hatched. The first or larval stage in insects is worm-like, with legs poorly developed. It is at this stage that the insects show their kinship with the annulata most clearly. During this stage the animals eat enormously, grow, and store up fat. It is in this stage, therefore, that they are most injurious to human interests. Grubs, maggots, caterpillars, army worms, tomato-worms, measuring-worms, wiggle-tails, are some of the names applied to the various larvæ of insects. The larval stage may continue for only a few days or for several years. During a period of rest, known as the *pupa* stage, the organs of the larva are resorbed and the new organs of the adult are developed from the stored materials in the body. Often this change is profound,—as from a crawling, leaf-eating caterpillar to a nectar-sucking moth with large wings. The adult is known as an *imago*. The adult life may be only long enough to deposit eggs, as in the May-flies;—or may be several years, as in the case of some queens among the social insects.

The metamorphosis in some of the crustacea (Figs. 82 and 83) is quite as striking as among the insects, but it follows a somewhat different course. There is no resting stage; but the change from larva to adult is made by a series of smaller changes that occur during successive moultings. In moulting the skeleton is separated gradually from the skin that has produced it. The animal bursts it at some point, and gradually frees itself by crawling out the rent. It is soft and helpless in this stage and usually hides. It grows rapidly, may change its shape

somewhat, and begins to secrete another shell. This may be repeated, as in the lobster, six or seven times before it becomes like the adult (Fig. 81). Moulting continues into adult life in those forms that continue to grow.

273. General Relation of the Arthropods to Nature.—

The great number of the arthropods insures two things: (1) that in many instances they will prove themselves pests to other organisms, both plant and animal, and (2) that many other animals will depend upon them for food. They are important scavengers and help rid the earth of its decaying matter; they attack all sorts of living plants and animals; they visit the flowers for pollen and nectar and carry pollen from flower to flower. So close is this adaptation between insects and flowers that some plants are entirely dependent on certain types of insect for the pollination. It is believed by botanists that insects have been one of the most important influences in the development of the flowering plants as we now have them.

Insects furnish the chief diet for many birds, lizards, toads, and mammals. The crustacea are a large part of the food of the fishes, both in fresh and salt water. As would be expected, many insects depend upon other insects for food.

Insects live through the winter either by hibernation or in the form of winter eggs. Their rapid power of reproduction enables them to come quickly to full numbers as spring and its vegetation appears.

Many arthropods have coloration and form of body that gives them protection by rendering them inconspicuous; but it is by no means clear that all the wonderful variety of colors we find among them is of direct use to the possessors.

There is good field for studies, on the part of the students, of special adaptations in insects to special modes of life. There is no other group of animals so favorable for this kind of investigation. For example, we may take an illustration in the form of the body itself. In the cockroach, which is kin to the grasshoppers, the body is very much flattened dorso-ventrally. This is interpreted as an adaptation to the habit of crawling and living in concealment under objects. In the case of the fleas, the flattening is right-left. This enables them to crawl with less difficulty among the hairs of the hosts upon which they live.

274. Relations of the Arthropods to Man.—Few of them are of direct use to man as food. The lobsters, crabs, shrimps, crayfish among the crustacea; and the honey of the bee, among the insects, about complete the list. Locusts are said to have been eaten in cases of extremity, where they have devastated the land.

The silk of the silk moth is important as a source of supply of a most beautiful cloth, and the web of spiders has been used in the same way, but not on a commercial scale.

Many of the plants useful to man are pollinated by insects. This is true of red clover, which is pollinated by the bumble bees, and of many of our fruits. But for a small fly, the formation of fruit by fig trees is impossible. This insect was not native to America and had to be imported before any success was possible in the fig culture of California.

In the adult stage they may destroy crops, spread contagious diseases, devour stored grain, and become a menace to man and the domestic animals. In the

voracious larval stage they devour waste material as scavengers, strip vegetation, spread disease, and furnish food to the higher animals. In both stages they may be parasitic on man and the other animals.

275. Definition of the Arthropoda.—The body is bilaterally symmetrical and made up of a series of homologous segments. The appendages are typically jointed (whence the name *arthropod*). The head is made up of three or more fused segments. There is an outer chitinous skeleton to which lime may be added. The nervous system is in the form of a chain ventral to the digestive tract, except for a ganglion (brain) above the gullet. Compound eyes are common, but not universal.

276. Classification and Key to the Phylum.—(The following keys are only intended to give the student an idea as to the manner of tracing the classification of animals. For exact work he must refer to the special books on insects.)

277. A Key to the Classes of Arthropods.

Chiefly water-breathers; four antennæ *Class Crustacea*.

Chiefly air-breathers.

Segments many and similar; two antennæ. *Class Myriapoda*.

Segments different in different parts and fused into regions.

Three body regions (head, thorax, and abdomen); two antennæ; six thoracic legs *Class Insecta*.

Two body regions; no antennæ; 8 thoracic legs,

Class Arachnida.

278. Key to Orders and Common Forms of Myriapoda.

Not more than one pair of feet to each segment; antennæ long; bodies flattened *Order 1, Chilopoda*.

Fifteen pairs of legs.

Eyes in facets (compound) *Scutigera*
(the "skein" centiped).

Eyes not compound, but numerous *Lithobius*.

Twenty-one to twenty-three pairs of legs. *Scolopendra*
(the poisonous centipedes).

Two pairs of feet to the segment; body cylindrical, antennæ short.....*Order 2, Diplopoda.*

Thirty or more segments; coils up when disturbed.....*Julus*
(the galley-worm).

279. Key to the Orders and to Some Common Forms of Crustacea.

Higher, larger forms; 19 pairs of appendages,

Sub-class Malacostraca.

Segments fused into cephalo-thorax; ten thoracic legs; eyes on stalks.....*Order Decapoda.*

Abdomen long and usually well extended.

Swimming forms*Penæus* (prawns).

Crangon (shrimps).

Creeping forms*Cambarus* (crayfish).

Homarus (lobster).

Abdomen soft and degenerate; inserted in shell of mollusk*Eupagurus* (hermit-crab).

Abdomen poorly developed; turned under thorax.

Body triangular in form; legs spider-like ..*Libinia*; etc.,
(spider-crabs).

Body rounded; broad in front and arched; legs short,

Cancer (burrowing crab).

Calinectes (soft-shelled crab).

Body roughly four-sided; one chela much larger than the other.....*Gelasimus* (fiddler-crab).

Thoracic segments free; eyes not stalked.*Order Arthrostraca.*

Body broad and flattened dorso-ventrally; gills on legs (*Isopoda*).....*Asellus* (water-bug).

Oniscus (sow-bug).

Porcellio (pill-bug).

Body flattened sidewise; legs partly adapted for swimming, partly for leaping.....*Gammarus* (sand-hoppers).

Smaller forms with variable number (usually less than 19) appendages*Sub-class Entomostraca.*

Attached in the adult; with limy shell,

Order Cirripedia (barnacles).

Lepas, goose-neck barnacle.

Balanus, acorn-shell barnacle.

Free-swimming forms (fresh-water forms only included here),

Water-fleas.

Carapace grows ventrally and forms protective shell.

Shell bivalved; body unsegmented; 7 pairs of appendages.

Cypris (*Ostracoda*).

Shell not bivalved, but folded and much larger than transparent body; swim by two large branched antennæ;
Daphnia (*Phyllopoda*).

No shell; body segmented.

Long, slender body; 11 pairs of leaf-like swimming feet,
Branchippus (Fairly-shrimp).
(*Phyllopoda*).

Short, pear-shaped body; two brood pouches at base of abdomen; 4 or 5 pairs of appendages,
Cyclops (*Copepoda*).

280. Key to the Chief Orders of Arachnida.

Parasitic forms with rounded bodies; minute; segmentation poorly shown Order 1, *Acarina* (mites, etc.).
Boophilus (cattle-tick).
Sarcoptes (itch-mite).

Free forms.

Long, jointed abdomen Order 2, *Scorpionida*.
Buthus (scorpion).

Soft, short, unjointed abdomen.

Very long slender legs Order 3, *Phalangida*.
Liobunum (harvest-men).

Legs of moderate length; poison glands .. Order 4, *Araneida*
(true spiders).

Do not spin web to catch prey (wandering),
Running spiders (*Lycosa*).
Jumping spiders (*Attus*).

Spin a definite web (sedentary).

Tunnel in ground; line it with web,
Trap-door spiders (tarantula).

Make tube of cobweb in the grass,
Tube-weavers (*Agalena*).

Spin irregular cobweb Net-weavers (*Theridium*).

Spin regular, geometric webs Orb-weavers.
(*Argiope*; *Epeira*, etc.)

281. Key to the More Important Orders of Insects.

Mouth parts suited for biting and chewing.

Wingless { Spring tail, and allies.
Degenerate members of other orders.

With two pairs of wings.

Wings unlike in structure.

Anterior wings somewhat thicker; posterior folding fan-wise beneath them Order *Orthoptera*.

- Anterior very thick and horny; posterior folding lengthwise and crosswise beneath *Order Coleoptera*.
 Wings nearly alike in structure.
 Many veins (nerves) in the wings..... *Order Neuroptera*.
 Few veins in wings..... *Order Hymenoptera* (in part).
 Mouth parts suited for piercing and sucking.
 Two pairs of wings.
 Wings unlike; front pair leathery at base,
Order Hemiptera (in part).
 Wings alike.
 Covered with powdery scales *Order Lepidoptera*.
 Membranous wings; not covered with scales,
Order Hemiptera (in part).
 One pair of wings..... *Order Diptera*.
 Wingless: degenerate types of several orders.
 Mouth parts suited for both biting and sucking; four transparent wings; front and rear wings fastened by hooks, and thus acting together *Order Hymenoptera*.

282. Key to Some of the Common Orthoptera.

- Legs similar; body flat; good runners,
Family 1, *Blattidæ* (roaches).
 Small brown species..... Croton bug.
 Large black species Cockroach.
 Legs similar; body slender; slow crawlers.. Family 2, *Phasmidæ*
(walking-stick insects).
 Legs unequal; third pair longer; jumpers.
 Antennæ shorter than the body. Family 3, *Acrididæ* (locusts).
 Medium size, with reddish legs..... Red-legged locust.
 Large; hind wings edged with yellow..... Carolina locust.
 Antennæ longer than the body.
 Ovipositor sword-shaped Family 4, *Locustidæ*.
 Small; green; in meadows. Meadow-grasshopper.
 Large; tree dwellers; green..... Katydid.
 Small; brown and wingless; under stones, etc.,
Cricket-grasshopper.
 Ovipositor awl-or spear-shaped; brown or black,
Family 5, *Gryllidæ* (crickets).

283. Key to Some Common Neuroptera.

- Living in communities in wood or earth; bodies white. Termites
(white ants).

Not living in communities.

Fore wings larger than hind wings; adult life short. May-flies.

Fore wings not larger than hind wings.

Wings folded over back when at rest. . . Agrion (damselfly).

Wings extended horizontally, when at rest, . . . Dragon-flies.

284. Key to some common Hemiptera.

First pair of wings thickened at base. . . *Sub-order Heteroptera*
(true bugs).

Land bugs.

Antennæ with four joints; outer half of front wing with many veins Squash-bug family.

Outer half of front wing with few veins. Leaf bugs.

Antennæ with 5 joints.

Brown or green; on fruits, etc. Bad odor. . . Stink-bugs.

Black, with red-yellow stripes. Calico cabbage bug.

Water bugs.

Short antennæ.

Body broad and flat; front legs } Giant water bugs,
for grasping, } "Electric-light" bugs.

Body oval or elongated; front legs not for grasping.

Back flat; swim right side up. Water boatmen.

Back like keel of boat; swim upside down,
Back-swimmers.

Long antennæ.

Legs long; suited to walking on water. . . Water-striders.

First pair of wings not thickened at base. . *Sub-order Homoptera*.

Do not live in colonies.

Large; antennæ minute; 3 ocelli. Cicadidæ (cicadas).

Black and green. Cicada tibicen
(Dog-day harvest-fly).

Black with bands and spots of red; } Cicada septendecim
appears at long intervals, } (17-year locust).

Small; antennæ minute; not more than two ocelli; triangular and of grotesque form. Tree-hoppers (Membracidæ).

In colonies on vegetation.

Small; antennæ long; 4 transparent wings, or none; legs long and slender; on leaves and tender growth. . . Aphides
(plant-lice).

Small; antennæ long; wings usually wanting; occur in scaly, cottony, or mealy masses anywhere on plants

Scale insects (Coccidæ).

285. Key to some common **Diptera**.

Without wings; external parasites.....Fleas, sheep-ticks, etc.

With wings (one pair).

Antennæ long; many segments.

Large, slender, with V-shaped suture in back of thorax,
Tipulidæ (crane-flies).Medium size; no V-shaped suture; scale-like hairs on margin
of the wingsCulicidæ (mosquitoes).Body parallel with surface when at rest,
Culex (common mosquito).Hind end of body raised when at restAnopheles
(malarial mosquito).Smaller; appearing in large swarms in air,
Midges, gnats, punkies.

Antennæ short.

With 5 segments (*i. e.*, 3d segment of antenna ringed),
Horse-flies (Tabanidæ).

Large, black.....Mourning horse-fly (Tabanus)

Smaller with banded wings..Banded horse-fly (Chrysops).

With three segments (third segment club-like and bearing
a dorsal bristle).Resembling bees; eggs laid on mammals; larvæ parasitic,
Bot-flies (*Estridæ*).Not resembling beesFlies (*Muscidæ*).Stripes on prothorax; mouth-parts not developed for
piercingHouse fly.

Similar, but able to bite; annoys stock....Stable fly.

Large, black; abdomen steel blue.....Blow-fly.

Black and white; banded wings; larva bores in sub-
stance of apples.....Apple maggot (fly).286. Key to some common **Hymenoptera**.

Females with oviducts suited to boring; no sting.

Abdomen with two saw-like structures*Tenthredinidæ*
(saw-flies; rose-slugs, currant flies).Abdomen with slender ovipositors; eggs laid in plant tissue,
where they produce galls.....*Cynipidæ* (gall-flies).Abdomen slender, with very long ovipositors; lay eggs in
tissues of other insects.....*Ichneumonidæ* (ichneumon flies).

Females with sting; oviducts not suited to boring.

Anterior wings not folded lengthwise.

First segment of abdomen lens-shaped, connecting the rest
of the abdomen with thorax.....*Formicidæ* (ants).

Large, black; bores into wood Carpenter ants.
 Small, brown; nests in ground Corn-louse ants.
 Head and thorax rusty red; rest black; makes ant-hills,
 Mound-building ants.

The small red ant belongs to the *Myrmicidæ*, a related family.

First segment of abdomen long and slender, connecting rest of abdomen with thorax *Sphecidæ*, etc.
 (Mud-daubers and digger-wasps).

Anterior wings folded lengthwise.

Body smooth, *Vespidæ* (wasps).

Abdomen long and spindle-shaped *Polistes* (wasps).

Abdomen thick and blunted,

Vespa (hornets, yellow-jackets).

Body more or less hairy *Apidæ* (bees).

Solitary Carpenter, and leaf-cutting bees, etc.

Social.

Large, nests in ground; black with yellow,

Bumble bees (many species).

Small; brown, with bands and patches of lighter colors,

Honey bee (*Apis*).

[The great orders Coleoptera and Lepidoptera cannot be treated satisfactorily in brief form. The student must be referred to such books as Comstock's "Manual for the Study of Insects" or to Kellogg's "American Insects."

287. Topics for themes in Zoology and English.

1. Sexual dimorphism and polymorphism among insects.
2. Adaptations for protection among the insects.
3. Alluring coloration and its supposed uses. Illustrations.
4. Is there any evidence of power of communication among the social insects, as the ants.
5. What senses seem best developed among the insects?
6. Courtship among the spiders.
7. Spiders' webs and their various uses. How are they produced?
8. Some insects have wings for a portion of their life

only. Investigate the conditions and find an explanation.

9. Why is moulting necessary among the arthropods? How is it accomplished?

10. Study the habits and the life history (field or library) of the following animals: hermit-crab; digger wasp; the ichneumons; the lobster; the bot-fly; the May-fly; the mosquito; scarab beetle; plant-lice.

11. Insects that mimic others.

12. Life in an ant-hill. An account of the kinds of ants and their various duties.

13. What is meant by the following terms: ants' cows; slave-making among the ants; army ants; agricultural ant.

14. Varieties of homes among the bees and wasps.

15. Symbiosis among the insects.

16. Modifications among the flowers to adapt them to insects.

17. Adaptations among insects to adapt them to flowers.

18. Give an account of an observed instance of insects pollinating flowers and the method of it.

19. Silkworm culture: methods and value.

20. Insects introduced from foreign countries.

21. The history of efforts to find enemies of some of our insect pests.

22. Give an account of Blastophaga and the fig culture.

23. How do bumble bees survive the winter?

24. What is cochineal and how produced?

25. Give an account of the following insect pests and their work:

Gypsy moth; codling moth; cotton-boll weevil; San José scale; cottony cushion scale; Hessian fly; Phylloxera; corn

aphis. To what orders do they belong and what modes are being used to meet their ravages?

26. Metamorphosis among the insects. How prevalent is it? What advantages has it over direct development?

27. Why have arthropods not succeeded in producing large massive bodies like the vertebrates or some mollusks?

28. The real underlying meaning of the statement that the number of the species of insects is greater than of all the rest of the animal kingdom beside.

29. Make special studies of the habits and activities of members of this phylum during the spring months.

30. Make a list of all the noxious insects known by you to be found in your locality. In what ways do they work their injury? What are the best methods of control? Why?

CHAPTER XXI.

PHYLUM XII: CHORDATA (VERTEBRATES).

288. **General Statement.**—To this point we have been studying the invertebrates, animals that have their hard parts on the outside. In the remaining phylum the skeleton is chiefly internal. It includes the fishes, the frogs, the lizards, the turtles, the birds, the mammals. In some of these there is an external skeleton also. The internal skeleton is more simple in the lower members of the branch. It consists typically of a long rod of tissue dorsal to the digestive tract and ventral to the nerve cord. In its simplest form it is known as a *notochord* and is of very delicate tissue. This gives the name *Chordata* to the whole group. In most the notochord becomes surrounded with cartilage or bone, and forms a real spinal (vertebral) column. These are the real vertebrates.

In the animals studied hitherto the nervous system has been on the ventral side of the animal and the heart dorsal. In the vertebrates the chief nervous centres are dorsal, and the heart is ventral to the digestive tract. (Compare Figs. 106 and 6.) In the vertebrates the breathing structures, whether lungs or gills, rise from the anterior end of the digestive tract (the *pharynx*); and in all the vertebrates, at some stage of life, there are slits from the pharynx to the outside world. These slits bear gills in the lower groups, but close up and disappear in the reptiles, birds, and mammals.

289. **Some Doubtful Forms: a Library Exercise.**—There are some lowly animals that stand in some respects intermediate between the invertebrates and the vertebrates. They have some of the qualities of the vertebrates men-

FIG. 106.—Cross section of a vertebrate, showing the arrangement of the principal organs. Diagrammatic. *ap.*, paired appendages; *b.c.*, body cavity; *ch*, notochord; *d.f.*, dorsal fin; *g*, gut; *h*, heart; *h.a.*, haemal arch (bony); *m*, muscles; *n.a.*, neural arch (bony); *sp*, spinal cord (nervous); *v.c.*, vertebral column.

Questions on the Figure.—Compare this figure carefully with Figures 6 and 57 (sections of invertebrates), and enumerate the principal differences in the arrangement of the important organs. Study the figure as an illustration of bilateral symmetry. Compare it with the cross-section of the sea-anemone (Fig. 51).

tioned above, and for this reason are especially interesting to the biologist, although they are not important animals in nature. These include the worm-like *Balanoglossus*, and the *Tunicates* or sea-squirts. Examine figures and descriptions of these in the texts and answer the following questions with respect to them:

FIG. 107.—Lake Lamprey (*Petromyzon*), clinging to sucker. From U. S. Fish Commission, by Surface.

Questions on the Figure.—What are the evidences that the Lamprey belongs to the Chordata? How would you describe the mode of life pictured here? Is it parasitism or simple preying? What mouth structure has the lamprey that fits it for this life? What references can you find to the breeding habits of lampreys?

Where do they live? What is there about their structure that suggests that they are chordates? What seems to relate them to invertebrates? What is the difference between the larval and the adult condition in the sea-squirts? Are there any tunicates that do not become attached when adult?

290. Some Lowly Chordates: a Library Exercise.—Here may be included the *Amphioxus* (lancelet); and the *Lampreys* (Fig. 107). In what respects are these closer

to the true vertebrates than the tunicates are? What do they lack of being real vertebrates? Where is *Amphioxus* found? How large is it? What are the habits of the lamprey? How does its mouth differ from that of the true fishes?

291. A Typical Vertebrate (the Frog): Field and Laboratory Exercise.—Either a fish or a frog may be used for this study, though the author prefers the frog if only one vertebrate is dissected. The student should be encouraged to make out his own outline and questions with respect to the habits, activities, powers, general form, and structure of the animal. The outlines for the crayfish and grasshopper (pp. 55 and 66) may be taken as suggestive if desired.

The following topics should be included and should receive such treatment as the time will allow.

A. Powers and Activities.—Place of living; its habits; methods of locomotion on land and in water, and the effectiveness of them; positions at rest on land and in water; food and method of capture (experiment by giving it living grasshoppers); breathing (make a careful study of all the motions accompanying breathing and interpret); length of time it can remain under water; its senses: kinds, and evidences for; position of its eyes and the advantages and disadvantages of this special position in actual life.

B. General Form and Structure.—Symmetry (compare with crayfish); differentiation of the anterior end; regions of the body, size and relation to one another; all special structures (included in) the head; appendages (compare with one another and with your own); joints and digits; all special markings, color, and the like. Make drawings of the frog in the rest position, showing form and

external structure. Compare as many species of frogs and toads as you can get with the species you are studying in these matters of general form and color.

C. *Internal Anatomy*.—The skin and its attachment to the body.

A study of the chief muscles revealed by removing the skin; especially those of the hind leg and of the ventral surface of the body. Make a diagram of their position, form, and attachments.

The organs as they lie when revealed by cutting the muscular wall covering the abdomen. Identify all, and draw in place.

Press the dark colored liver aside and find the relation and comparative length and size of the following: esophagus, stomach, intestine, rectum. How is the intestine held to the body wall? Open the digestive tract from end to end and compare the regions.

Remove the digestive tract and find the kidneys, the fat bodies, and the reproductive bodies in the dorsal part of the body cavity. How do you identify these? Are there any outlets for the kidney or the ovaries and testes? What is the sex of your specimen? How do you know?

Look well front for the lungs. How many? How attached? Do they communicate with the mouth? Cut them open and examine the inner surface.

The heart; what is its position in relation to the other organs? What is its shape? its attachments? Cut into it carefully and see how many chambers it has. Can you find any large vessels leaving the heart? From what portions? Determine, by reference to the books, what these are.

The course of the circulation can be studied only by injecting a colored mass into the aorta while the tissues are soft, after chloroforming. After this treatment the principal vessels may be dissected. A large frog should be used for this purpose.

Find the white, glistening nerves, after removing the organs from the body cavity. How many are there? Where do they arise? To what regions do they run?

The skeleton may be studied by picking and scraping away the muscles and connective tissue. A little boiling will make this more easy.

The student should identify the following regions and study the bones that enter into each:

The axial skeleton, made up of the head, and the vertebræ, and the breast bone; the appendicular skeleton, made up of the legs and the bones to which they are attached (*girdles*). The follow-

ing questions will suggest the kind of studies that the student should outline for himself: Do the appendages unite directly to the axial skeleton? How many vertebræ are there? What is a single vertebra like? How much difference is there between those least alike? Are there any ribs? How many bones in the hind leg? How do the joints work? How much of the skull is brain-case? How does the lower jaw work? What makes the frog's head so broad? Where are the teeth? How many parts in the *sternum* or breast-bone? How much cartilage do you find about the skeleton of the frog?

The study of the central nervous system will require a second specimen. The most careful dissecting is necessary to cut away the flesh and bone from the back of the skull and vertebræ in such a way as to show the brain and spinal cord without injury. If this is done, the following questions, among others, should be answered: Is the nervous system bilaterally symmetrical? Why? Where is the most of the nervous matter located? Why? How many regions are there to that part of it that is in the skull? Which is the largest of these lobes? By lifting up the brain, beginning at the front, examine the sides and bottom of the brain for nerves. How many pairs do you discover? Do any nerves arise from the spinal cord? Compare with those studied in the body cavity.

After drawing all that you have found, compare your work with figures and descriptions in the larger texts, and label your drawings.

D. *The Life History of the Frog*.—A most interesting series of studies may be made by beginning in March or April to collect the eggs from the ponds. Either watch them day by day in the ponds or, better, arrange some large vessels in the laboratory, where the eggs may be hatched. Some green water plants will be of advantage in the vessel. Keep account of all the changes and the time required for them. Study the activities, as breathing, feeding, sensitiveness and the like in the tadpoles. The circulation of the blood may be studied in the young tadpoles, in the gills and the tail. Find specimens outside beginning to develop legs. What becomes of the tail? What becomes of the gills?

292. **Classification.**—The principal divisions of the Vertebrates are:

Class 1.—Pisces (*e. g.*, sharks, lung-fishes, bony fishes).
Page 281.

Class 2.—Amphibia (frogs, toads, newts, salamanders).
Page 296.

Class 3.—Reptilia (crocodiles, lizards, snakes, turtles).
Page 306.

Class 4.—Aves (birds). Page 317.

Class 5.—Mammalia (mammals, including man). Page
343.

CHAPTER XXII.

CHORDATA (CONTINUED): CLASS FISHES.

293. **General Statement.**—Most of the fishes that the student will find are so characteristic that he will have no trouble in recognizing them at once. They are interesting because of their graceful and rapid motions in the water, for which the shape of their body so well adapts them, and for their strength and gameness when caught. They constitute the largest class of vertebrates and are found in all waters, fresh and salt. They vary in length from one-half inch up to the great basking-shark which may be as much as thirty-five or forty feet in length.

The body is commonly elongated, pointed at both ends, and thin from side to side; but we find all sorts of departures from this, in certain cases, in adjustment to special kinds of life. Some fish become nearly globular; others are long and snake-like, as the eels. The ribbon fishes are long and flat; the skates are flat from back to belly. Many deep-sea fishes are quite grotesque in form.

Many fishes, particularly in tropical waters, are highly colored; and in many instances the coloration is such as to give protection to the possessor, though this is by no means always true.

294. **External Features: Appendages and Scales.**—The appendages of fishes have the form of fins. These are folds of the skin supported by rays of harder material.

The fins are, typically: a median fin along the back (*dorsal*), a large median fin over the tail (*caudal*), and one ventral just in front of the tail (*anal*); a pair of fins on the side close to the gills (*pectorals*); and a pair, variable in position, but usually further back and closer to the belly (*pelvics*). Of these the powerful tail fin is the one most used in locomotion; the others probably aid in steering and in holding an upright position. The pectoral and pelvic fins are believed to correspond to the arms and legs of higher animals, but they never have the fingers and toes which are so characteristic of the higher types. Examine all the figures that you can find showing variation in the bony structure of fins of fish. The most of the fishes produce some sort of scales in the skin. These are bony or horny plates that overlap like shingles and make a protective armor. In some forms, as in the catfish and eels, they are wanting or are so deep set in the skin as to be invisible. In others, as the sturgeon and gar, the scales may be fused in such a way as to make a rather heavy armor.

295. **The Skeleton and Muscles; Locomotion.**—The internal skeleton of the fish supports the muscles, and these two elements give the form to the body. In its simplest form the skeleton is cartilaginous, as in the sturgeon and some sharks, and in the embryos of all fishes. It consists of a case in which the brain lies (*cranium*), followed up by a series (twenty-four, more or less) of *vertebræ* extending along the back clear to the tip of the tail. This is the axial skeleton. To the *cranium* a great many bones, loosely fused, are attached (Fig. 108). These form the jaws and gill-arches. From the *vertebræ* of the body arise ribs which partly sur-

round the body cavity. The vertebræ of the tail do not bear ribs. On the dorsal side of each vertebra there is a little arch that protects the nerve cord. Compare Fig. 109, A and B.

The muscles of a fish are in segments, as will be seen by the student on examining a piece of baked fish. These

FIG. 108.—Skull of cod (*Gadus morrhua*). From Nicholson.

Questions on the Figure.—How much of this figure is brain case (cranium)? How much is made up of facial bones? Compare this with Fig. 122, and other references, in this respect. Note how loosely the jaws (*p.m.*, *m.*, and *d.*) are joined to the cranium.

extend from rib to rib or from the middle of one vertebra to the middle of the next. The muscles are heaviest about the level of the vertebral column, and thin off along the sides of the body on the ribs. The tail, which may make up as much as one-third to one half of the body, is a solid mass of muscle acting on the row of vertebræ. It is a powerful organ and when supplemented by the broad tail-fin makes a most effective propeller.

Moving in the water as the fish does he has four problems: propulsion; horizontal steering; vertical steering; and keeping himself upright in the water. The tail is the organ that controls the first. Difference in the strength of the right and left strokes of the tail will turn the animal to right or left; this would be aided by the action of the small fins. The paired fins can be used to steer up or down. Probably the air-bladder, a long

FIG. 109.—Diagram of vertebræ of a bony fish. A, caudal; B, trunk; c, centrum or body of vertebra; ch, notochord; h.a, hæmal (or visceral) arch surrounding hæmal cavity (h.c.); n.a., neural arch, surrounding neural (nervous) cavity (n.c.); r, rib.

Questions on the Figure.—In life, what occupies the neural cavity? What occupies the hæmal cavity in the tail region? In the trunk region?

internal organ filled with gas, assists in this. If the muscles of the posterior part of the body wall are contracted, the air in the bladder will be pushed forward and this end will be of less specific gravity than the posterior end, and will be pointed slightly upward as the animal swims. The reverse would be accomplished by contracting the anterior body muscles. This would aid

FIG. 110.—Diagram of the principal vessels in the circulation of a fish—ventral view. *a*, aorta; *au*, auricle; *br.a.*, afferent branchial arteries; *br.e.*, efferent branchial arteries; *bu*, bulbus of the artery; *c*, carotid artery; *c.a.*, caudal artery; *c.v.r.*, right cardinal vein; *d.a.*, dorsal artery; *d.c.*, ductus Cuvieri; *g*, gills; *h.v.*, hepatic vein; *h.p.*, hepatic portal vein; *i*, intestine; *j*, jugular vein; *k*, kidney; *l*, liver; *r.p.*, renal portal vein; *s.v.*, sinus venosus; *v*, ventricle. For the sake of simplicity, the auricle is represented as posterior to the ventricle.

(*operculum*). The gills show as red filaments when this is lifted. The heart has one auricle and one ventricle, and handles impure blood. It forces the blood into arteries that carry it to the gills. It is gathered from these into a large artery that carries it to all parts of the system, where it does its work through the capillaries. There are four important regions where the blood is modified on this course. What happens to it in each of the following: in the muscles of the body; in the walls of the digestive tract; in the kidneys; in the liver? It returns to the heart through large veins.

297. **Food and Digestive System.**—The food of fishes is as diverse as possible. Some, as the sharks, are fierce and carnivorous, preying on forms as large or larger than themselves; other, and these are the most numerous class, depend upon small animals, such as worms, crustacea, insects, and the young of their own or other species of fish; some live largely on plants. Some fish are scavengers and live upon the dead matter found in the waters. The microscopic animals and plants which occur in such immense numbers are important items of the food supply of fishes. The digestive tract is varied in accordance with the type of food used—the vegetable feeders having a longer intestine, as is always true. The following regions are usually to be distinguished: the mouth, which may have teeth on the roof as well as on the jaws; the pharynx, in the side walls of which the gill-slits and gills are; a short œsophagus leading to the stomach which is an enlargement of the tract, varying a good deal in shape and size; from the stomach a smaller tube, known as the intestine, leads, with one or more coils, to the anal opening. The stomach very often has a number of hollow,

finger-like pouches of its wall (*cæca*) near its opening into the intestine. These secrete digestive juices, and possibly assist in absorbing food. Fishes have a liver which may have a bile duct connecting with the intestine.

298. Nervous System and Sense Organs.—While the brain is less developed in the fishes than in the other vertebrates, it is probably more complex than in any form we have studied yet. That part of the nervous matter inside the cranium is known as the brain. It has right-left symmetry. Beginning at the front there is a small

FIG. 112.—Brain of fish, side view. *cb*, cerebellum; *c*, cerebrum; *o*, olfactory lobe; *ol*, olfactory nerve; *on*, optic nerve; *op*, optic lobe; *m*, medulla oblongata.

Questions on the Figure.—What is the meaning of the terms applied to the parts in the figure? What is suggested by the fact that the brain is in lobes? What is believed to be the particular functions of the various regions?

pair of *olfactory* lobes supplying the sense of smell. These are connected by stalks to the next lobes (*cerebrum* or *forebrain*). Behind these are a somewhat larger pair of lobes (*optic lobes*) which control vision. Back of the optic lobes is a single lobe known as the *cerebellum* and behind this the *medulla oblongata*, which tapers into the *spinal* cord. From the medulla and the spinal cord the chief nerves of the body arise, except those of smell and sight. The function of the forebrain appears to be to

control and coordinate the activities of these lower centres. Trace these structures in Fig. 112.

The fishes have the sense of touch developed in the skin; a chemical sense (similar to taste and smell) that gives some information of the condition of the water, located in the nostrils, and possibly on the snout and in the mouth; a sense of mechanical jar, and possibly of sound, in the ear and the organs of the "lateral line"; and a kind of gravity or equilibrium sense located in the ear. The eyes are well developed and are similar in general plan and structure to those of higher vertebrates. (Fig. 159.)

299. Reproduction and Development.—The sexes are separate in fishes, as in all the higher vertebrates. The ova and sperm are produced in great numbers. The ova (*spawn*) are usually deposited in the water in shallow places on the open bottom, under rocks, or in nests prepared for them by the parents. The sperm (*milt*) is poured over these by the male and the fertilization and later development are left to chance. Great numbers of eggs are laid, the most of which perish. In a few cases some care is given to the young by the parents. In some types the eggs are fertilized and the young hatch in the body of the mother. Only a few young are produced in these cases.

The eggs of fishes have considerable yolk and the young usually hatch out in the adult form.

The breeding habits of many fishes are exceedingly interesting. The mature salmon live in the sea; but when spawning time comes they migrate in great shoals up the fresh-water streams, leaping all sorts of obstacles in their effort to get to the cool head-waters. Here the eggs are laid and the young pass through the early stages of their

development, gradually working their way back to the sea. It is on these migrations of the salmon in the rivers of western America that they are caught and canned for the market.

Some of the eels are known to generate in the sea and spend their later life in the fresh water.

FIG. 113.—Atlantic salmon (*Salmo salar*). U. S. Fish Commission.

Questions on the Figure.—What are the names of the various fins shown in the figure? What is the dotted line along the side of the fish?

300. The Main Types of Fishes.—There are two orders of fishes that are important because of their numbers and present development, and two orders that are interesting chiefly because of their evolutionary importance.

The sharks, skates, and saw-fish (*elasmobranchs*) are fierce and powerful marine fishes. They are of lower development than the next group. The skeleton is often wholly cartilaginous. The mouth is not at the end of the head, but is on the under side. The gills do not have a cover as in the higher fishes. The two parts of the tail fin are not equal.

The common bony fishes (*teleosts*) such as the trout,

the salmon, the herring, the bass, the mackerel, the eel, etc., include about 10,000 species, or two-thirds of the whole group. Few others come under the observation of the student. They have a bony skeleton in the adult, have the mouth at or near the end of the head, and have symmetrical tail fins.

Sturgeons and gar-pikes (*ganoids*) illustrate a group of fishes not very large at the present time, but of great

FIG. 114.—Brook trout (*Salvelinus fontinalis*). U. S. Fish Commission.

geological importance. They were the dominant fishes of the so-called geological "age of fishes." They are covered with bony plates which give them complete protection. The internal skeleton is usually cartilaginous, though it may be bony. These forms have the air-bladder connected with the gullet in such a way that they can actually take in and give out the air by bringing the mouth to the surface of the water. The air-bladder is well supplied with blood vessels, and thus almost deserves the name of lung. They include the sturgeons, the gars,

the bow-fin, and a few other types that are found in our lakes and rivers.

The lung-fishes (*dipnoi*) include three or four species from widely separated parts of the world, and are remarkable because of the great development of the air-bladder. This becomes a real lung and is of use to them as the rivers in which they live become partially dry. They are mud-

FIG. 115.—Long-eared Sun-fish (*Lepomis auritus*). Photo from life by Shufeldt.

fishes. One species comes from the rivers of Australia, another from South America, the others from Africa.

The paired appendages of these animals are less like fins and more like legs or flappers. In these respects the *dipnoi* stand somewhat intermediate between the fishes and the amphibians.

301. **Economic value of fishes** is very great and is destined to become more so as we learn how to breed and care for them and increase the edible forms at the expense of the non-edible. It is necessary only to mention the names of some of the food fishes to realize their value. The salmon, the cod, the herring, the mackerel, sardines, whitefish, halibut, menhaden, catfish, are some of the most used fish. Hundreds of other species are edible.

Indeed a larger percentage of the well-known species of fish are considered edible than of any other group of animals.

For a great many years little care has been taken of the fish, and the result is that many of the most valuable fish are being rapidly exterminated by the heavy drains made upon them by fishermen. The national government and many of the states are now taking steps to control the fishing, to hatch and bring the young fish through the

FIG. 116—Sheepshead. Greatly reduced. Photo from life by Shufeldt.

dangerous stages artificially, and to maintain the food supply of the fishes during the whole year. Intelligent care should in time stock the fresh waters with edible fish, and keep them so that a steady supply may be had from them without reducing them. The hatcheries are even hatching the ocean fish and trying in this way to increase the cod and other marine types. This is of value because it is in the egg and in the earliest stages that greatest havoc is wrought by the enemies of the species, and if they can be protected at this time, larger numbers will come to maturity.

302. Definition of the Class Pisces.—The fishes are cold-blooded aquatic vertebrates, breathing by means of gills throughout life. They have a two-chambered heart. Their paired appendages are fin-like and do not develop toes. The skin usually develops bony or horny scales or plates.

303. Key to the Common Orders.

No operculum covering gills. *Order Elasmobranchii*.

Bodies elongated, and rounded in section,

Sharks (dog-fish; saw-fish; etc).

Bodies flattened dorso-ventrally. Skates and rays.

Gills covered with an operculum.

Body partly or wholly covered with plates,

Order Ganoidei (Long-nosed gar; sturgeon).

Body not covered with plates; skeleton bony,

Order Teleostei.

Air bladder connected with intestine by open duct,

Sub-order Physostomi.

Marine: Smelt; salmon (Fig. 113); shad; herring; eels.

Fresh water: Trout (Fig. 114); whitefish; suckers; carp; pickerel; muskalonge; minnows; catfish.

Air bladder when present not opening into the intestine.

Dorsal, anal, and pelvic fins spiny in front,

Sub-order Acanthopteri.

Marine: Mackerel; toad-fishes; sculpin; silversides.

Fresh water: Perch; stickleback; sunfish (Fig. 115); darters.

Dorsal, anal, pelvic fins not spiny,

Sub-order Anacanthini.

Marine: cod; haddock; turbot; sole; and other flat-fishes.

304. Topics for Themes in Zoology and English.—1. Probable origin of fresh-water fishes. What forms are now able to go back and forth from fresh to salt water? Why may not any fish do so?

2. Get data about the habitat, food, breeding habits, distribution, economic importance (and the reasons there-

for) of the following fishes: salmon, trout, muskalonge, herring, eel, cod, flat-fish, mackerel, shark, sturgeon, gar-pike, bow-fin.

3. The habits of the lung-fish that would suggest how the lung might be of value to them.

4. Migrations among the fishes.

5. Parental care among fishes.

6. The number of eggs produced by different species. The reason for.

7. Study figures showing the embryology of the salmon or other bony fish.

8. What do we mean by "game" fish?

9. Report on some one or more of the great fishing industries and the methods and processes in use in them: the salmon fisheries; the cod; the menhaden; or the herring.

10. The banks of Newfoundland in relation to fishing. Why important?

11. Make a report on the habits and conditions that are worthy of inquiry in respect to the following anomalous fishes: the flying fishes; the angle fishes; the electric eel; the flounders or flat-fish; the blind fish of caves; the fish of very deep waters.

12. The chief points of variability among fishes, and the reasons for the differences.

13. Spring studies of fishes. Is there any difference between their behaviour at this time of the year and that of other seasons?

14. The U. S. Fish Commission. Its organization; its purposes; its methods; its publications.

CHAPTER XXIII.

CHORDATA (CONTINUED): CLASS AMPHIBIA.

305. **General Statement.**—There is no more interesting group of animals than the amphibians, which include the frogs, toads, salamanders, and newts. They stand midway in habits between the fishes which use gills all their lives and reptiles which use lungs only. The typical amphibian starts life as a tadpole with gills. Gradually the gills give place to lungs, the adult breathing air. There are a few that never have anything but gills, and a few that develop lungs at once, without any tadpole stage.

The skin does not produce scales, but is usually glandular and slippery when moist, like that of the eel or catfish. They are cold-blooded like the fishes. The heart has two auricles and one ventricle. Their paired appendages, when present, are leg-like and have toes.

It will be seen that the amphibians are similar in many respects to the fishes, especially to the dipnoi; and equally clearly they have passed beyond them in their development.

It is the smallest of the classes of vertebrates.

Since the frog has already been studied in the laboratory as a type of the vertebrates (Ch. XXI), a detailed account of the structures will not be given here.

306. **The Skeleton and Form of the Body.**—The salamanders and their allies have a long body with a tail, somewhat like the fishes; but the frogs and toads lose

the tail, when adult, and the body becomes much shortened. In the tailless types, particularly, the changes in the form of the body are related to the development of legs. As the strong legs develop, the bones of the legs become better grown and the connection with the inner skeleton becomes more firm. In connection with these legs also, the muscles of the body itself, those that act on the vertebræ, become relatively less important and the great muscles are the ones that move the legs. This places the bulk of flesh at a different point and the shape of the animal changes correspondingly. In most of the long-tailed forms the legs are comparatively weak.

There is a breast-bone in the amphibians, but the ribs are very little developed. The bones about the head are more closely fused than in the fishes.

307. Respiration and Circulation.—Reference has already been made to the fact that the early form of breathing is by means of gills. They are much like the gills of fishes in position and number. The circulation in the tadpole must of course take the blood to these gills to be aerated, and hence the course of the circulation at first is quite like that in fishes. As the lungs grow and gradually take the place of the gills, certain blood vessels going to the lungs increase and those going to the gills change their form in such a way as to give quite a different appearance to the adult vessels in this region (Fig. 117). The heart undergoes some changes to correspond to this. In the fishes the heart handles impure blood only, the pure blood going from the gills to the system. In the adult frog the pure blood goes back at once from the lungs to the heart, in addition to the impure blood that returns from the system. The pure and

impure blood go into separate auricles, but there is only one ventricle and the two kinds get mixed more or less, as both auricles empty into it. On the whole, the circulation and aeration are more perfect than in the fishes, but the animals are not yet warm-blooded. The skin in all these animals is important as a respiratory organ.

FIG. 117.—Diagram of the heart and arterial arches of the frog. *a*, aorta; *c*, carotid; *d.a.*, dorsal artery; *l*, lung; *l.a.*, left auricle; *p.a.*, pulmonary artery; *p.v.*, pulmonary vein; *pre.c.*, precaval vein; *post.c.*, postcaval vein; *r.a.*, right auricle; *r.j.*, right jugular vein; *v*, ventricle. 1-4 the branchial arches of the aorta corresponding to gill arches in the fishes.

Questions on the Figure.—How does the heart compare with that of the fish? What is the course of the blood in the parts figured? What kind of blood comes to the left auricle? To the right? Is there anything to suggest that the impurest blood will go to the lungs?

308. **Habits of Life and Food.**—While most amphibians have lungs in the adult stage the great majority of them like to remain close in reach of water, and many of them spend most of their lives in it. The fact that their eggs must be laid in the water doubtless brings this about. The soft, unprotected nature of their skin also makes it necessary. The insects and worms, snails, crustacea, and small fishes, that they use for food are found abundantly in such regions. None of the amphibians live in salt water. The frogs and the water forms have more enemies than the toads. Chief among these are the wading birds, fishes, and snakes. The common toads are active chiefly after dusk and the tree toads are often colored in such a way as to be inconspicuous. In the case of the frogs their white bellies render them less conspicuous to the enemies below them in the water; and their green and rusty brownish colors, less visible to enemies from above.

Their quick leap is also puzzling to a pursuer, as has doubtless been discovered by the members of the class who have undertaken to capture them.

309. **Reproduction and Development.**—Most amphibians breed in the early spring. The eggs are laid singly or in masses and are surrounded by a gelatin which swells up on entering the water and protects them and holds them together. They are fertilized after leaving the body of the mother. Only a few days are required for hatching and escape from the gelatinous envelop as a young tadpole. Fig. 118 will illustrate some of the steps in the later development. The most important fact to be remembered and studied is the metamorphosis through which they go. This metamorphosis involves from the

outside the loss of the tail, the loss of gills, the development of legs, and a corresponding change in the shape of the body. Within, the changes are just as profound. The lungs develop, the circulation changes, the long coiled digestive tract suited to vegetable feeding becomes relatively shorter and adapted to the adult diet; the

FIG. 118.—The metamorphosis of the frog. After Brehm. Numbers indicate sequence of stages.

Questions on the Figure.—How much of the egg is really ovum? Enumerate the changes that take place in passing through the various stages? In what order do the legs appear? How is respiration effected after stage 6? After stage 11?

sexual organs develop. All this takes place while the animal is actively living and using all its powers. It does not go into a resting stage as do many of the insects.

This change is made in the life-history of a single individual. Zoologists believe that the ancestors of the higher air-breathing forms were originally water-breathers, and that, through long series of generations, they

have gradually changed from gills to lungs just as the frog does in one generation. Indeed the belief is that the amphibians have just been caught in crossing the stream, so to speak, and have become adapted to this as a permanent mode of life.

310. Place in Nature.—The group of amphibians is not large, consisting of about 1,000 species. The tailless forms are well distributed in the fresh waters of the earth. None of the species have large individuals. The "Giant Salamander" of Japan may attain a length of three feet. They are of little economic importance. The toads destroy a good many insects and thus help in holding this group in check. Toads are easily reared artificially, and might be made much more valuable in this respect by increasing their numbers. The legs of some of the larger species of frogs are prized for eating. They are a delicate, light-colored meat. Frogs have been used very widely in laboratories for dissection and for experiments on the nervous system. A large amount of our knowledge of the functions of the various portions of the central nervous system, and of the way in which muscles and nerves act, is derived from the study of this animal.

311. Chief Types of Amphibians.—There are two important orders of these animals: the *Urodela* or tailed forms (Fig. 119), and the *Anura*, or tailless forms (Figs. 120 and 121). The latter are more common and better known to the average student.

Newts and salamanders are elongated and appear much like the lizards. Their bodies are smooth, however, instead of scaly as in the lizards. The type most likely to be found by the student is probably the blunt-nosed

salamander, of which there are several species. It has a series of yellow spots on a background of black or greenish-black. It belongs to the genus *Amblystoma*, and is found in moist places beneath logs, in cellars, or even in cisterns. It is six or eight inches in length. The water dog or "hell-bender" is found in the Ohio river and its tributaries.

FIG. 119.—Tailed amphibians. From Mivart. A, *Siren*; B, *Amphiuma tridactyla*; C, *Necturus*.

Questions on the Figure.—Compare these three types and note all the chief differences of external structure. Compare also with figures you may be able to find of other Urodela.

The newts are smaller and are found in ditches and sluggish brooks, under sticks and stones. The species vary in color from yellow and reddish to olive green and even duller colors.

The mud-puppies (*Necturus*) do not lose their gills in the adult, and are rather common in the rivers, ponds, and lakes of the northern United States. They may reach a length of two feet.

Toads and frogs lose the tail and always lose the gills.

FIG. 120.—The common toad (*Bufo lentiginosus*). Photo by Folsom.

FIG. 121.—Frog (*Rana*). Photo by Folsom.

Questions on Figures 120 and 121.—What is the round object back of the eye? Compare the figures and note points of similarity and difference. What in their position puts them in readiness for a quick spring? Where do toads lay their eggs? What of the feeding habits of the toad? Where do they spend the winter?

The three principal families are the frogs, the toads, and the tree-toads. They include 80 per cent., or more, of the species of amphibians. One of the largest is a toad of the Bermudas, which is the only form that develops in partly brackish water. Many of the toads have most remarkable breeding habits, adapting them to their conditions of life.

312. Key to Some of the Common Amphibians.

With tail in the adult; body elongated.....*Order Urodela*.

Gills persistent through life.....*Perennibranchiata*.

Body eel-like; hind legs wanting,

Siren, or mud-eel of the South.

Body lizard-like; hind limbs present,

Necturus; mud-puppies.

Gills lost, but slit remaining.....*Derotremata*.

Limbs rudimentary..Congo snake of the Southern States.

Limbs well developed....*Cryptobranchus*, the hell-bender.

All traces of gills lost.....*Mictodera*.

Six to 8 inches long; black with yellow spots,

Amblystoma, salamanders.

Three to 4 inches long; olive green or brown,

Spelerpes, newts.

With no tail in the adult.....*Order Anura*.

Suited for climbing and living in trees,

Hyla, etc. (tree-toads).

Land forms; more active at twilight,

Bufo (the common toads).

Land and water.....*Rana* (frogs).

Body green.

Large, faintly spotted; head pale green,

Rana catesbiana (bull-frog).

Small, uniform green, with small dark spots,

Rana clamitans (green frog).

Small, with irregular splotches of black, edged with white,

Rana halecina (leopard frog).

Body not green.

Bright brown on back; two rows of oblong, dark brown splotches on back. *Rana palustris* (pickerel frog).

Pale reddish brown; legs and arms barred with brown,

Rana sylvatica (wood frog).

313. Topics for Themes in Zoology and English.

1. Give an account of the breeding habits of the following forms: The obstetrical toad of Europe; the Surinam toad of South America; the pouched tree-frogs of South America.

2. Give the history of the Mexican axolotl.

3. The color changes of the tree toad, *Hyla versicolor*. How are they produced?

4. The amphibians in geological history.

5. The noises made by frogs. How are they made and what is their value?

6. How do frogs spend the winter? How do toads?

7. Make definite studies of amphibians and their behavior during the spring months.

CHAPTER XXIV.

CHORDATA (CONTINUED): CLASS REPTILIA.

314. **General Statement.**—We have now for the first time a group of vertebrates that do not breathe by gills at any stage of life. They may live in the water, but they are air-breathing from the time they are hatched. In this respect they are like the birds and mammals. All of these higher classes, however, show their kinship with the fishes and amphibians in having rudimentary signs of gills in the early embryonic stage, before hatching or birth. These are never used and all external signs of them soon fade away. All the reptiles are cold-blooded and in this they agree with the lower classes rather than with the higher.

When the term reptile is used, most people think of the snakes; but the snakes are the least typical of the reptiles. The lizards and the alligators are more nearly like the main stock of reptiles. The turtles also belong to the group but they, like the snakes, are in some degree degenerate animals. At least they have become so specialized as to cease to be fairly representative.

The class of reptiles was at its height in the Mesozoic age of the earth, or the "age of reptiles" as it is called. At this time there were great land reptiles, as is shown by the fossils, 60 or 70 feet in length, and 20 feet high. Others equally huge lived in and ruled the seas. Still others, much smaller, had membranous wings like those of the bats, and were the first vertebrates to learn to fly

FIG. 122.—Skull of rattlesnake (*Crotalus durissus*). From Nicholson.

Questions on the Figure.—How much of the figure is brain-case (cranium)? Which are the bones of the face? Notice how loosely the bones of the jaws (*ar*, *de*, *mx*, etc.) are joined to the cranium. Compare the various bones with those of the fish and bird (Figs. 108 and 130). Study the position and articulations of the quadrate bone (*qu*) particularly. What advantage is there in this arrangement? Compare the quadrate in other vertebrates by examining figures.

FIG. 123.—*Rhamphorhynchus merensteri*—a restoration of an extinct flying reptile. From the Cambridge Natural History, after Geikie.

Questions on the Figure.—In what respects does a form like this differ, in external appearance, from a bird? From a bat? What skeletal structures would a palæontologist need to find in order to believe that an extinct form had the power of flight?

(Fig. 123). With the exception of a few sea-turtles, the alligators and crocodiles, and the boas and pythons, all of the living species are small.

With the exception of snakes, the reptiles are covered with bony scales or plates in such a way as to furnish much protection. In the case of the snakes the scales are thinner, more superficial, and are shed periodically.

315. Practical Exercise for the Library.—By reference to all the pictures and descriptions you can find, supplemented by your own knowledge of these animals, prepare a paralleled column report comparing lizards, alligators, turtles, and snakes in respect to the following points: (1) haunts and general mode of living; (2) kinds of food and means of capturing it; (3) the general form of the body; (4) the appendages—their number, position, joints, fingers; (5) the covering of the body and the materials of which it is composed; (6) the mode and efficiency of locomotion; (7) breeding habits and care of young.

316. Practical Exercise for the Field and Laboratory.—Enough specimens of turtles, of snakes, and of lizards can usually be had to enable the members of the class to make some record of observations either in the field, or in the laboratory, or both. The following and similar topics may be investigated.

1. What is the effect of changes in temperature upon the activities of reptiles?
2. What are the differences between the scales of fishes and of snakes? Between those of snakes and lizards?
3. Can you find evidences of special senses? Where are the organs located? What peculiarities seem worth noting?
4. Tell in detail just how the snakes move. Can they climb trees? How is it done?
5. Do you find anything to suggest protective coloring? Describe and test.
6. How many different kinds of snakes, turtles, and lizards are found in your locality? Record any differences of habit and distribution that you discover. Supplement this by reference to the authorities.

317. Respiration and Circulation.—As has been intimated, the reptiles are pure air-breathers, and their lungs

are more complex than those of the lung-fishes or the amphibians. In respect to circulation which we have seen to be so closely related to the respiration, the reptiles are intermediate between the lower and higher vertebrates. The temperature of their blood is controlled by the outside conditions and not by the rate of oxidation on the inside, and hence they are called cold-blooded. The heart in most of them is three-chambered, as in the amphibians; but in the crocodiles there are two complete auricles and two ventricles as in the birds and mammals. In these the blood from the system and the blood from the lungs do not mix, as happens in the amphibians and the lower reptiles. The general arrangement of the arteries and veins is much as in the higher vertebrates.

318. **The Chief Orders of Reptilia.**—For a view of the numerous extinct types of reptiles the student should refer to the geologies. The four modern orders are to be considered as remnants, highly modified to meet special conditions of life.

The *Lacertilia*, or Lizards (Figs. 124 and 125).—These little animals are shaped much like the salamanders, with which they are often confused. They are easily distinguished from them by the rather stouter legs, the presence of scales in the skin, and the presence of claws on the toes. In this group are included, beside the forms commonly recognized, the chameleon, which is gifted with great power of changing color; the horned toad, of the western part of the United States, which is not a toad at all; the Gila monster, of the Southwest, which is one of the largest of the lizards and the only one known to be poisonous; and the legless "glass-snakes" of the South, so called because of the ease with which the body breaks

into pieces. It is generally true that the tails of lizards are easily broken. They have the power of regenerating or regrowing the lost part.

FIG. 124.—The swift lizard (*Sceloporus undulatus*). Adult. Photo by Shufeldt.

The *Ophidia*, or snakes (Fig. 126), have lost their legs, except the merest rudiments in a few forms, and possess a very slender, much elongated body. By a peculiar arrangement of the bones, the snakes have the power of opening the mouth to an extent not found in other animals

FIG. 125.—Flying lizard (*Draco volitans*). Nicholson.

Questions on Figures 124 and 125.—What suggests that these animals are reptiles? In what respects are these lizards similar? Different?

FIG. 126.—Common garter snake (*Eutania sirtalis*). Photo by Shufeldt.

(see Fig. 122). This enables them to swallow living objects much larger than the body itself. There are several species of snakes that are poisonous, and this fact has given the whole group a bad name which they do not deserve. The poison gland is one of the salivary glands modified; and the poison fang is a modified tooth. The chief poisonous types are the vipers of Europe, the cobra of the East Indies, the rattlesnake, the copperhead, and the water-moccasin of our own country.

FIG. 127.—Common box-tortoise (*Cistudo carolina*). Photo by Shufeldt.

The pythons, the boa, and the anaconda capture and crush their prey by the muscular fold of the body. These are the giants of the order. Other common types are the green-grass snake, the garter-snake, the water-snakes, and the black-snake. These are not poisonous.

The turtles (*Chelonia*, Fig. 127) have short, wide bodies which may be flat or much arched. There are two protective cases—the arched *carapace* above, and the flattened

plastron below. The head, tail, and legs of the creature emerge from between these structures. Because of this heavy armor the turtles are ungainly animals; but equally because of it they can well defy most enemies by merely withdrawing the exposed parts and remaining quiet.

The water forms are usually known as turtles; those that live on land as tortoises. Some of the sea-turtles are large. The great leather-backed turtle is said to reach a weight of half a ton. The green turtle of the Atlantic coast is much used in the making of soups. The large hawk-bill turtle of the tropical seas has an

FIG. 128.—Head of the American alligator (*Alligator mississippiensis*). From Eckstein.

outer covering which furnishes the “tortoise-shell” of commerce. The snapping turtles are fresh-water types and are quite ferocious in disposition. Fairly common are the box-tortoise, the painted turtle, the soft-shelled turtle, and the speckled tortoise.

The *Crocodylia* (Fig. 128) are aquatic, living in the swamps and sluggish waters at the margins of the great rivers. There are some twenty species, two of which are found in the southern United States. Others are found in the Nile, the Ganges, and the other great tropical rivers. The alligator is smaller and has a somewhat broader snout than the crocodile.

319. Reproduction and Development.—In the reptiles, as in the bird and mammals, the fertilization takes place inside the body. It must occur before the egg is encased in its shell, which is added in the lower part of the oviduct. The eggs of the reptiles are large, similar to those of birds. They are usually deposited in small numbers in depressions or holes in the ground or in the sand at the edge of the water, or under stones or other objects. For hatching they must depend upon the warmth of the sun or of decaying organic matter in which they are sometimes placed. Usually little care is given after laying; but the alligators guard their nest and the young. Some snakes and lizards retain the eggs in the body until hatched.

In all these forms the young, when it leaves the egg, is a miniature of the adult, and able to care for itself. There is no metamorphosis.

320. Place in Nature.—The reptiles are for the most part sluggish animals. Many of them like to lie and bask in the sun. The largest species are tropical forms. They are muscular and are capable of rapid motions, but this is not so continuous as in the birds. Cold weather always checks their activities. Those that inhabit temperate regions hibernate in winter.

The reptiles live largely on animal food, such as worms, insects, fish, small birds and mammals, eggs, and the like. Not a great many animals depend on the reptiles for food. They seem rather less preyed upon than most animals. Some of the predaceous birds eat snakes and lizards.

As a group they are relatively of little importance to man one way or the other. The cobra of India is said to cause 25,000 deaths in one year; but aside from this the

fatalities are simply occasional. The poisonous type are being rapidly exterminated. The teeth and skin of alligators and crocodiles; the tortoise-shell; the flesh of some turtles embrace about all the direct contributions which the class makes to humans.

321. Definition of the Reptilia.—The reptiles agree in breathing by means of lungs throughout life; in having scales of horny or bony material developed in the skin; in producing eggs of considerable size; and in being cold-blooded.

322. Key to the Principal Orders of Reptiles.

With a box-like covering.....*Order Chelonia* (turtles).
Soft-shelled; aquatic; plates of carapace not completely bony, covered with a leathery skin,

Soft-shelled turtle (several species).

Hard-shelled; land or water.....*Testudinidæ*.

Land forms; can withdraw completely into box, and close flaps of plastron.....Box-tortoise.

Water forms:

Head large; not withdrawn into carapace; given to snapping its beak in defense. Snapping turtles (several species).

Head and neck not so long; plates of carapace dark brown bordered with yellow,

Painted, or mud-turtles (several species).

Without box-like covering.

Body long and slender; no legs.....*Order Ophidia*.

Head flat and triangular, with small scales; tail blunt; venomous*Crotalidæ*.

Examples: Rattlesnake; copperhead; water moccasin.

Head tapering into body and covered with plates; tail more tapering; non-venomous*Colubridæ*.

Examples: Grass snake; garter snake; water snakes; spreading adder; black snake.

Body lizard-like, with four legs.

Small; cloaca opening by a transverse slit.*Order Lacertilia*.

With wide body; spines on head.....Horned toad.

With slender body.

Body gray, with undulating, dark transverse bands,

Swift, pine lizard, or alligator lizard.

Body dark green, with longitudinal yellowish lines;
tail blue. Blue-tailed lizard, or skink.

Large; cloaca opens by longitudinal slit. . . *Order Crocodilia*.

323. **Topics for Themes in Zoology or English.**—1. Report on the following adaptations among reptiles and their value: the spreading head and hostile attitudes of non-venomous snakes, like the spreading adder; the breaking and regeneration of the tail; the rattles of the rattlesnake; the poison and fangs; the carapace of turtles.

2. What of the length of life of reptiles? What would their sluggishness have to do with this?

3. Why can reptiles afford to produce so few young in a season?

4. The snake in myth.

5. The various methods of capturing prey among the reptiles.

6. What possible reasons (causes) for cold-bloodedness?

7. The method and meaning of hibernation in animals. Illustrations among the reptiles.

8. Color among the reptiles. Where located? Value.

CHAPTER XXV.

CHORDATA (CONTINUED): CLASS AVES (BIRDS).

324. **General Statement.**—Birds share with mammals the first place in the animal kingdom. They share with insects—the most specialized of the invertebrate branches—the highest development of the power of flight found among animals. Add to this their great variety of color, their great abundance, and their interesting diversity of habits and instincts, and we have the most attractive group of animals in the whole animal series to the general student and lover of nature.

Birds are the most easily recognized of all the animals. This means that the structural differences among them are relatively slight. They do differ greatly in their habits of life, however. Some, as the ostrich, cannot fly and only run about on the land; others, as the penguins, cannot fly, but are excellent swimmers and live on or about the water; most can fly well and may frequent either land or water.

Notwithstanding the ease with which they may be recognized, the birds have some interesting likenesses to the reptiles. They have scales on the shank and feet; they lay large, well-nourished eggs, which hatch outside the body; the digestive tract and the excretory and reproductive organs open into a common chamber (*cloaca*), and this communicates with the outside by a single opening; the structure of the ankle-joint is very similar in the two groups. Furthermore, the early geological birds

(Fig. 133) were very much more like reptiles than those of the present day. The conclusion which zoologists draw from these facts is that the birds and the reptiles are from a common stock and are related.

325. **Practical Exercises for the Field and Laboratory.**

—The time that can be given to the study of birds in an elementary course should be given wholly to the study of the habits and relations and activities, and of such broad adaptations of the bodies as will help to explain these. In these studies of the life relations of birds the student should not neglect to study their relation to human life and welfare. The excursion, the camera, and the field-glass are the means which should be used. A few mounted specimens, a captive bird, and a mounted skeleton will be of much help. Each student, or a group of students, should be encouraged to select one or more species of birds, and be asked to study their habits and general form in the light of some such outline as the following:

I. *Habits and Activities*.—Haunts and feeding habits. How widely does it wander from the region where it most likes to be? What kinds of food does it prefer? At what time of day is it most active? In what way does it get its food? How take its water? Why the difference? What organs does it use in getting food? In what ways are these organs well suited to their work?

Social habits: are they solitary or gregarious? Do they differ at different seasons in this respect? Why?

Mating habits: monogamous or polygamous? Degree of difference between the sexes? Time of mating.

Nesting habits: number of eggs, their size and other characteristics. Character, structure, and position of the nests. Watch carefully the building. Is the color

of the eggs of any conceivable use? Which sex incubates the eggs? Condition of the young at hatching as compared, for example, with the chick. What care is given by the parents to the young? What part is taken by the male? How often and with what are they fed? How long in the nest?

Determine and describe the powers of song. Are they equally developed in all individuals of the species? Can you cite any evidence to prove that the power of song is of any use to the bird?

Migrations. Are there any evidences of winter or other migration? If not, how is the winter spent? If so, at what time does it occur? When does the species return? Secure information as to where it has been in the meantime.

Power and peculiarities of flight. Other modes of locomotion. Is its power of perching well-developed? Characteristic motions or positions.

What are its relations to other animals of the locality? Has it any enemies? Is it hostile to any species of animals? Does it in any way help or hurt human interests? Show in what way and to what degree.

What is its abundance or scarcity in your locality? Can you assign any explanation for the facts you have observed? Does man have any influence in this respect?

II. *General External Appearance*.—The regions of the body—head, neck, trunk, limbs. Make a record of everything you can discover in respect to these regions, their relation to each other, their size, the organs and parts which they show.

The covering of the body. Compare the color of all the visible parts. Is there any color-pattern? If so how is it formed? Select specimens of all the types of

feathers you can find and indicate from what part of the body they come. In what respects do they differ? What is the value of each kind? How are the feathers arranged on the body? Is there any regularity, or are they all over the body as the hair on mammals? Study carefully the structure of a large feather.

See if answers can be found to the following questions:

What are the similarities between the front limbs (wings) and the hind limbs? Where is the knee, and where the ankle-joint of the bird? In general what are the qualities of the neck in the birds? What end is gained thereby? Is the trunk of the bird flexible? What is the value of this condition?

How many toes in the bird? Is this the case in all birds? Are all the toes equally developed? Are they all turned forward? Is this arrangement found in all birds? Is there any connection between the closing of the toes and the flexing of the leg? Value of this? Are the eyes movable? Do they view the same field? Do the two command the whole field without turning the head? What is the nictitating membrane? Its use? Is there any ear? If so is it more like that of the frog or that of man?

III. *Comparative studies of the bird population should be made, if possible.* For this purpose a food box with a small opening which will allow a little food to be exposed all the time will attract many birds in the winter and early spring (Fig. 129); a drinking and bathing place in the spring and summer will do the same. A mere piece of suet hung up in a tree brings the birds. All these should be put where the observer can approach without disturbing the birds.

Make a written report on the *disposition* of the common

species of birds. Are they timid or aggressive? Friendly or quarrelsome? Your evidences.

How do the following differ as to their favorite places of living: partridges; doves; wrens; robins; woodpeckers; blackbirds; thrushes; owls; kingfishers? Select one other type that is like each one of these in respect to place of living.

FIG. 129.—Sectional view of a food-box for birds, to aid in winter study. May be put at top of post or hung up by the hook at the side of a tree. It should front south. The nails (see figure) should be frequent enough to prevent the waste of food.

Make a study of the colors of birds. Do the sexes usually differ in color? In what way? In what ways may these color differences be of value to them?

Compare the nesting habits of the various common birds of your acquaintance. Compare them also as to the degree of activity and the ways in which they express it; as to the mode of flight; the notes of song; the social instincts, and the like.

326. Skeleton and General Form of the Body.—The skeleton, which gives the form to the body of animals, is much fused in the trunk of the birds. The vertebrae are fused, the ribs have stays which bind them together,

the breast-bone is strong and wide, and still other bones help to give a firm yet light framework suitable for the attachment of the muscles of flight. The neck, on the contrary, is slender and flexible. One of the most re-

FIG. 130.—A right lateral view of the skull of the American flamingo (*Phenicopterus ruber*). Photo by Shufeldt.

Questions on the Figure.—Distinguish upper and lower jaws, comparing them as to massiveness. Is this the usual condition in birds? How much of the skull is occupied by the brain? To what habits of the flamingo is the form of the beak an adaptation? Compare this figure with Figs. 108 and 122.

markable bones in the flying birds is the breast-bone. It is large and has a keel, extending vertically from it, to which the heavy muscles of flight are attached. The flat breast-bone does not present enough surface for this purpose. There is a close correlation between the length

of the neck and of the legs in birds. The student should verify this by his own observations. The chief muscles of the bird are those of the legs and of the breast. If the muscles are much used they are dark; if little used light, as in the breast of the turkey. Why?

FIG. 131.—Diagram of the stomach and oesophagus of the fowl. *o*, oesophagus; *c*, crop; *p*, proventriculus or glandular stomach; *g*, gizzard or grinding stomach; *i*, intestine.

Questions on the Figure.—Compare this stomach with Fig. 147 in respect to complexity. What are the functions of the various regions? Why is the crop located outside the cavity inclosed by the ribs?

327. Food and Digestion.—Birds eat more food in proportion to their size than any other animals probably. This is connected with their great activity and their high temperature, which is even greater than that of the mammals. Birds may live on fruits and berries, on seeds and grains, on insects and other small animals, on decaying flesh, or may capture living prey, as fish, reptiles, frogs, or even other birds. Their beaks and claws as well as the internal parts of the digestive organs vary according to the nature of the food. Probably the most striking internal difference is in the crop and the grinding

stomach, or gizzard, of the grain-eating birds (Fig. 131). The action of such an organ is needed because of the lack of teeth in the mouth. The intestines are long and coiled.

328. Respiration and Circulation.—The heart is completely four-chambered and there is no mingling of pure and impure blood. In addition to the lungs, there are air sacs in various parts of the body which are connected with the lungs. Some of these may even extend into the larger bones. This gives a larger surface for the exchange of oxygen and at the same time renders the body lighter than if it were solid. The breathing of birds and the heart beat are more rapid than in the other groups. These facts contribute to the hot-blooded condition of the birds and to their ceaseless activity.

329. The Nervous Activities and Structures.—The brain is larger in proportion to the size of the animal than in the reptiles. This increase is found especially in the *cerebrum* and *cerebellum* (see §298). The larger brain is associated with the great activity of the animal, especially the demands of balancing and flying, as well as the highly developed instincts of mating, nesting, caring for the young, and so forth. The eyes are large and efficient. It appears that the sense of sight and hearing are better developed in birds than the other senses. It is thought that the sense of smell is not very acute. The bird is what we would call a "nervous animal." It is alert, it is sensitive, and it is quickly responsive.

330. Reproduction and Development.—All birds lay large eggs in which there is stored enough food to bring the embryo well along in its development before hatch-

ing. The eggs must be fertilized within the body, because the "white" of the egg and the shell are added by the oviduct after fertilization. Because of their warm-bloodedness the young must have warmth in which to develop. This is usually supplied by the body of the mother in

FIG. 132.—Nestling marsh hawks (*Circus cyaneus*). Year-Book Department of Agriculture.

Questions on the Figure.—What are the nesting and breeding habits of the marsh hawk? Are the young precocial or altricial?

sitting on the eggs. The number of eggs laid varies from one to twenty or more. The time necessary for hatching varies roughly with the size of the eggs, from ten to fifty days. Most birds rear only one brood each year; some rear two, and the English sparrow may produce five or six in a season.

The nest itself varies from a mere hole in the sand or

earth, as in the case of the ostrich, to very carefully made swinging baskets, such as those made by the oriole, the tomtit, or the tailor bird.

The young in such forms as the chicken or the quail are well developed when they hatch. Very soon they are able to run about and seek their own food (precocial young). In the case of the pigeon or the blue-jay, the young are poorly clothed and are helpless for a much longer period (altricial young). The higher forms are the longer dependent. (See Fig. 132.)

FIG. 133.—*Archæopteryx lithographica*, an early reptilian bird. From Claus.

Questions on the Figure.—What in the figure shows it to be a bird? What shows it to be different from typical birds? What is signified by each of the terms in its scientific name?

331. The Principal Orders of Birds.—The sub-divisions of this class do not mean as much as in the other classes of vertebrates. The birds are more alike, and the divisions are based on activities and superficial structures. There are sixteen or seventeen orders of which the student may likely see representatives. For fuller description of these orders the student should refer to more extended

texts or to some of the many good bird-books now being published.

*The Ostriches, Cassowaries, etc. (Ratitæ).—*The ostrich (Fig. 135) is the best known representative of these flightless birds. They are the largest of all birds. Their wings are very rudimentary, but their legs are well developed and are powerful both for motion and for defense. There are a dozen or more species and all are

FIG. 134.—*Apteryx australis*. From Romanes.

Questions on the Figure.—What are the peculiarities of this bird? What does *apteryx* mean? What is the distribution of this species? What are its nearest relatives among the birds?

found naturally in the southern hemisphere, and chiefly in the old world. The feathers, or plumes, of the African ostrich particularly, are highly valued, and the ostrich farms are profitable in California and South Africa.

*The Auks, Penguins, Grebes, and Loons (Pygopodes).—*These are all aquatic birds, and are expert divers and swimmers. The penguins and auks have poorly developed

wings. Their legs are far back on the body and this gives them an awkward upright position on land; it accounts, however, for the ease of their swimming and diving movements. The loons and grebes are found in the fresh

FIG. 135.—Ostrich (*Struthio*). From Wood's Natural History.

Questions on the Figure.—Which of the types of feathers found in ordinary birds become the plumes in the ostrich? What is the real size of the ostrich?

waters, and the penguins, auks and puffins are marine. The latter form nest in great numbers on the rocky coasts, often being so thick as literally to cover the surfaces that are level enough to be occupied. The great

auk of North America has become extinct within the last century.

Albatross, Petrels, Shear-waters, Terns, and Gulls (Longipennes).—This is a group of aquatic birds with long, pointed wings. They are splendid fliers and some are also good swimmers; but they live about and over the water rather than upon it. They are gregarious, and this

FIG. 136.—Wood duck (*Aix sponsa*). Photo by Folsom.

is particularly noticeable at breeding time when they swarm on sandy or marshy shores or upon the rocky coasts, laying their eggs in crude nests or on the bare rock. These are the most common birds of the sea-shore and the high seas. The gulls (Fig. 137) and terns frequent also the inland waters.

Cormorants and Pelicans (Steganopodes).—These are

large water birds in which all four of the toes are united by the web. They are heavy eaters, living chiefly on fish. They are expert fishermen—the white pelicans

FIG. 137.—Ross' gull (*Rhodostethia rosea*). Upper figure adult male; lower, young female. From "Chapters on Natural History," Shufeldt.

Questions on the Figure.—What indications of structural adaptation to habits do you find in the figure? What differences do you find in the sexes?

even fishing together and driving their prey before them into shallow water, where they capture numbers of them in the pouch of the lower jaw (Fig. 139).

Geese, Ducks and Swans (Anseres).—These are familiar birds (Fig. 136) with heavy body and characteristic form. Their feet have three toes united by a web. The bills are broad and have a saw-like edge for cutting. They feed upon vegetation or on the smaller water animals. They are interesting because of their annual migrations.

FIG. 138.—Green heron (*Ardea virescens*). Photo by Shufeldt.

The ducks and geese spend the winter in the tropics and nest in the colder regions. There are said to be forty species of ducks, sixteen species of geese, and three species of swans native to North America.

Cranes, etc. (Paludicolæ).—This group includes the marsh birds, which either wade or stalk about the shallow

waters picking up the small animals to be found there. They are characterized by long legs and a correspondingly long neck. The rails and the coots, or mud-hens, belong

FIG. 139.—Pelican (*Pelecanus erythrorhynchus*). By Folsom.

Questions on the Figure.—What is the nature and purpose of the fold beneath the jaw? To what division of birds does the pelican belong?

to this group. Closely related to these are the storks, the herons (Fig. 138), the egrets, and the bittern—all shore and wading birds.

Snipes, Woodcock, Sand-pipers, Plovers, Killdeer (Limicolæ).—The small birds of this group frequent the sandy or marshy shores, and have long slender legs and long bills. They are of quick, active habits, taking advantage of cover, and are for these reasons “game” birds and sought by hunters. They and their eggs are often protectively colored, and the young are able to take care of themselves soon after hatching.

The Eagles, Owls, Hawks, Vultures (Raptores).—These are the birds of prey. Their adaptations consist of stout curved beaks and sharp curved claws, of powerful wings, and possibly of especially sharp vision. The vultures live on carrion and are scavengers; the others capture living food consisting chiefly of fish, small mammals, and of the smaller birds. They are usually easily recognized. The owls (Fig. 141) are among the most interesting of these because of their nocturnal habits and their striking adaptations to this sort of life.

Quails, Partridges, Grouse, Pheasants, Turkeys (Gallinæ).—These birds have a very characteristic form (Fig. 140). The body is somewhat stout and plump, the legs are short and armed with short, blunt claws. The beak is stout and bent downward at the point. As a rule, they are not capable of long flights. The order furnishes many game birds and is the most important to man in the amount of food supplied to him. Highest among these is the common domesticated chicken, or barn-yard fowl. The egg and fowl industry is one of the most important of the country, amounting, according to estimates, to more than 400,000,000 dollars annually.

It is one of the large sources of human food. Turkeys, guinea-fowls, and peacocks contribute in less degree. The numerous varieties of chicken are believed to have come, by breeding and selection, from a wild species native to southern Asia. The game birds of this order would

FIG. 140.—Ruffed grouse (*Bonasa umbellus*). Photo by Folsom.

quickly become extinct in settled regions, but for the laws protecting them at critical seasons.

Closely related to the Gallinæ are the doves and pigeons (Columbæ). It is a small order of about a dozen species which are native to America. None of these are now very numerous. Formerly, the passenger pigeon occupied the region east of the Mississippi River in great flocks of millions of individuals, but is now extinct or on the

verge of extinction. The numerous varieties of cultivated pigeons are descended from a wild European species, the blue rock-pigeon.

The Woodpeckers (Pici).—These well-known birds

FIG. 141.—Great horned owl (*Bubo virginianus*). Adult female. Photo by Shufeldt.

Questions on the Figure.—What are the habits of the owl? Does the figure show any structural adaptations to its known habits? How does the standing position of the owl differ from that of most birds?

have two toes directed forward and two backward in adaptation to the position they take in climbing. The tail has stiff, pointed feathers which aid them in climbing. They have sharp, strong bills and a long protrusible tongue for the capture of insects. The nests are made in

FIG. 142.—Belted kingfisher (*Ceryle alcyon*, L.). About one-fourth natural size.
Photo by Folsom.

holes in trees excavated by the birds. Many of them have striking coloration. This is one of the most interesting groups for the beginner to study.

Near these are placed the cuckoos, the kingfishers, and the toucans or horn-bills. The kingfisher (Fig. 142) and the rain-crows, or American cuckoos, are the only species of these last-named birds the student is likely to find.

The chimney-swifts, whippoorwill, and the humming-

birds are somewhat intermediate between the forms just spoken of and the next order.

The Perching Birds (Passeres).—This is the great order of birds, including more than 6,000 species—a greater number than all the other orders put together. They have three toes in front and one behind, which adapts them to perching. They are the common birds of field and meadow and orchard. Many of them have striking powers

FIG. 143.—Clark's crow. U. S. Dept. Agriculture:—"North American Fauna."

of song. Eighteen subdivisions or families of this order are recognized in this country, of which the best known are: the fly-catcher family (*Tyrannidæ*), including the kingbird; the crow family (*Corvidæ*, Fig. 143); the family of sparrows and finches (*Fringillidæ*), including also snowbirds, crossbills, grosbeaks; the oriole family, (*Icteridæ*), including orioles, bobolinks, meadow lark, and the blackbirds; the warblers (*Mniotiltidæ*), small migrating birds with bright colors and most attractive qualities; and, finest of all, the thrush family (*Turdidæ*),

including the various thrushes (Fig. 144), the robin, the bluebird, and the mocking-bird.

332. **Relation to Nature.**—It will be seen from the foregoing description that the birds, while much alike in fundamental structure, have succeeded in adjusting

FIG. 144.—Wood thrush (*Hylocichla mustelina*). Female, one-half size. By Folsom.

themselves to a remarkably varied life. The food, the special environment, the locomotion, the nesting and breeding habits, the relative length and size of the various external structures, as neck, beak, legs, toes, claws, wings, and tail, are subject to remarkable variations in meeting the various demands of life. The number of species

is a mark of their success in life. Man himself has probably proved the worst enemy of the birds, indirectly as well as directly. Much of their success is due to the instincts of nesting and care of young.

333. Relation to Man.—Some birds, as the English sparrow, eat chiefly grain, seeds, and fruits. Such are sometimes something of a pest to man. Unquestionably, however, the chief source of food of the small landbirds is the great group of insects. The birds, more than any other group of animals has kept down the insect population. They might almost be considered as engines to destroy insects. If all the birds were suddenly destroyed, unquestionably many species of insects would increase to the point where they would be a fearful pest to mankind, before a new balance in nature would be struck. These facts are at the bottom of the agitation of recent years that egg collecting and the slaughter of birds for "sport" shall stop,

Large numbers of weed seed are destroyed by birds. An observer found 7,500 seeds of one common weed in the stomach of one dove. Mice and other hurtful rodents are captured by owls and other preying birds. The ducks and geese and the orders to which the barn-yard fowl and the pigeons belong are the only orders that are likely to supply any large amount of human food. But, as in the case of the fishes, these are destined to be reared with much more care and success in the future than has yet been true. They now, for the most part, receive little of the attention of the farmer, and yet they furnish the surest and most profitable returns that he gets.

Of no less importance to man is the color and song and poetry of the bird life. It has attracted thousands to

the fields and the woods. Man cannot get back to nature in an open-minded and appreciative way without being the gainer.

334. Definition of the Class.—The birds are marked by the fact that they are bipeds in which the skin develops feathers, instead of scales or hair; the front appendages are usually suited to flying. The jaws are covered with a horny beak and do not bear teeth. They are warm-blooded and lay the largest eggs found among animals.

335. Practical Exercise.—Identify, by means of keys in some bird book, at least ten of the native species of birds.

336. Key to the Principal Orders of Birds.

Birds with no keel; incapable of flight. . . . *Order Cursores (runners).*

Examples: Ostrich, rheas, emus, apteryx, cassowaries.

Keeled breast-bone; mostly flyers *DIVISION CARINATÆ.*

Toes united by web, or fringed with web, for swimming or diving.

All four toes in the web *Order Steganopodes.*

Examples: Cormorants and pelicans.

Only three toes in the web.

Feet far back; wings short *Order Pygopodes (divers).*

Examples: Auks, penguins, loons, grebes.

Feet more forward; body heavy; wings broad,

Order Anseres.

Examples: Ducks, geese, swans, flamingo.

Feet more forward; long pointed wings,

Order Longipennes (sea-flyers).

Examples: Gulls, tern, petrels, albatross.

Toes only slightly if at all webbed; long legs for wading; neck and beak long.

Hind toe higher than the others.

Larger birds. *Order Paludicolæ (marsh birds).*

Examples: Cranes, rails, mud-hens.

Smaller birds. *Order Limicolæ (shore-birds).*

Examples: Snipe, woodcock, plovers, curlews, sandpipers.

Hind toe not higher than others *Order Herodines.*

Examples: Heron, ibis, bittern.

Toes not webbed; suited for walking or perching.

Chiefly terrestrial; legs short; claws and beak stout,

Order Gallinæ.

Examples: Chicken, turkeys, guinea-fowl, pea-fowl, quail, grouse.

Chiefly aerial and in trees.

Two toes forward and two backward *Order Pici.*

Examples: Woodpeckers; sap-suckers, flickers, horn-bill. (The parrots, the cuckoos, and some others belong near here.)

Three toes forward.

Claws strong, curved and sharp; beak hooked,

Order Raptores (preying birds).

Examples: Eagles, falcons, hawks, vultures, owls.

Claws short and blunt; beak weak and straight,

Order Columbæ.

Examples: Doves and pigeons.

Claws long, weak, slightly curved for perching; beak nearly straight; legs slender; usually with singing apparatus *Order Passeres* (perchers).

Examples: Crows, jays, finches, thrushes, warblers, etc.

337. Topics for Themes in Zoology and English.—I.

Compare the flight of the buzzard, the woodpecker, and the quail.

2. The rate of flight in birds. The length of time they may remain on the wing.

3. The social and gregarious instincts of birds. Are their social habits different at different seasons?

4. The annual succession of instincts in birds: the preliminary migration; mating; nest building; laying; sitting; care of the young? then what?

5. What birds of your locality are permanent residents? Summer residents? Winter residents? Migrants (stopping only a short time in spring and autumn as they pass through)?

6. Make a general study of migrations among birds, collecting the facts as to range of migration, place of

spending winter and summer, time of migrating, causes, and the effects on the species and its geographic distribution. Is it believed that birds migrate, from year to year, to the exact localities of former years?

7. Molting in birds. What makes it necessary? The time of its occurrence; different rate of molting; its effects on the bird, etc. The changes of plumage in the ptarmigans.

8. The diversity in the mating habits of birds. Describe the difference in the habits of the males in polygamous species and those in monogamous species.

9. A study of the nests of birds: materials, location, mode of construction, completeness, etc. Relation between the character of the nest and the development of the young at hatching.

10. The number of eggs laid by different species. The reasons for the difference so far as they can be ascertained.

11. Compare the vocal powers of birds and the vertebrates hitherto studied. Have their notes any relation to their state of mind? Are the males or females more vocal? Reasons. Where are the "vocal cords" in birds?

12. Discover the *peculiar* habits and adjustments of the following birds: the egg laying of the old-world cuckoos; the weaver bird of Africa; the flamingo; Apteryx; the humming-birds.

13. Make a study of the food of birds from Bulletin No. 54, U. S. Department of Agriculture; or Judd's "Birds of a Maryland Farm."

14. Outline still other studies of the spring activities of birds as compared with those of other seasons.

15. Birds and the injurious insects.

16. Classify the various services that birds render to mankind.

CHAPTER XXVI.

CHORDATA (CONTINUED): CLASS MAMMALIA.

338. **General Statement.**—The mammals are, on the whole, the highest vertebrates. Here we include forms as widely different as the kangaroo, the whale, the seals, the horse, the lion, the bats, the monkeys, and man. It will be seen that they differ more among themselves than the birds do, and yet they agree in some quite interesting facts. They all develop certain glands which in the female produce milk. These (*mammary*) glands give the name to the class. Instead of feathers, the skin develops hair. There may not be much, as in the whales, but even in these a certain amount is found, especially in the younger stages.

The mammals are like the birds in being air breathers, warm-blooded, and in having a four-chambered heart. The birds are more highly specialized in some respects and the mammals in others.

The lowest types of mammals, the *monotremes*, are like the birds in the fact that they lay large eggs and the young are hatched from these. But all the other mammals produce small eggs which are partly developed in a special organ (*uterus*) of the mother; and when the young are brought forth they are already similar in form and structure to the adult, though they are not able to take care of themselves. In the *marsupials*, the second division, the young are very immature and are placed in a pouch (*marsupium*) on the outside of the body in the

pelvic region, and are nourished here until they are mature enough to run about (opossum, Fig. 149, or kangaroo). The third and highest division of the mammals consists of the *placentals*, in which there is a close connection between the young and the mother. The period of internal nourishment is longer, the young being

FIG. 145.—Diagram of a trunk vertebra of a mammal. *c*, centrum; *ch*, position originally occupied by notochord; *h*, head of rib (*r*); *h.c.*, hæmal cavity; *n.a.*, neural arch; *n.c.*, neural canal; *st*, sternum; *s.c.*, sternal cartilages, uniting ribs to sternum; *t.p.*, transverse process of vertebra against which the rib works.

Questions on the Figure.—Compare all the parts here with corresponding ones in Fig. 106. What is gained by the attachment of ribs to a sternum? What is lost? What is the value of having the attachment cartilaginous? Which vertebræ bear ribs in mammals? Why do not all the trunk vertebræ bear them?

much more mature and like the adult when born. This period varies from three weeks in the mouse to twenty months in elephants. It is related in some degree to the size of the animals.

It will be seen that the two principal points mentioned—the mammary glands and the development in the uterus—are both devices to care for young. There is no group

of animals which gives as much in the way of successful parental care to the young. Because of this the higher mammals bring forth fewer young in a lifetime than any other class of animals.

339. Library Exercise: a Comparison of Monotremes, Marsupials, and Placentals.—By liberal use of the reference books, and in parallel columns, make a contrast of the three divisions of mammals in respect to the following particulars: Their geographical distribution; their peculiarities of structure; the eggs, and their size and structure; the gestation or internal development; the peculiarities of the brain.

340. Field Exercise: An Enumeration of the Domestic Species, and of the Native Wild Species of Mammals of Your Community.—Seek to get a complete list of these mammals, and put in groups those that seem most similar to you, enumerating the grounds for your classification. In doing this get together all the facts you know in respect to the following points: the general mode of life; the foods used and the manner of getting it; the size and form of the body; the character of the jaws and teeth; the form and size of legs and the character of the toes; the powers and special methods of locomotion; the external covering; mating habits; the number of young at a birth; the mammary glands, their number and position; the methods of caring for the young; the social habits; special organs, as horns, tusks, and the like; their bearing on human welfare.

341. The Nervous System and the Mental Qualities of Mammals.—The brain of mammals, especially the fore-brain or cerebral hemispheres, is of relatively large size. In the placentals this part of the brain, instead of being smooth like that of the birds, has folds or *convolutions* which increase the amount of its outer surface (Fig. 155). This outer surface is especially rich in the nervous cells, or "gray matter," and the intelligence of animals is roughly proportional to the amount of these cells.

The mammals have all the senses that the other vertebrates have, and these are well developed on the whole, although they are unequally perfect in the various types.

The sense of smell is very highly developed in some mammals; more so than in any other vertebrates probably. The external ear, as well as the sensory part of the internal ear, reaches its highest form in the mammals.

The mental life of animals depends on the structure of the brain, the character of the senses, and the connections that exist between these and the muscular tracts of the body. While we cannot get into the animal mind, we can experiment upon animals and measure what takes place inside by the responses that occur outwardly. We must remember, however, that we are liable to make the mistake of assuming that the animal mind has undergone all the steps that the human mind would take in coming to a certain line of action. While the action might be much the same as in man, the mental processes are almost certainly much simpler and more direct.

After making all allowance for this fact, however, it is certain that many mammals have some power of remembering experiences and of changing conduct in accordance with these experiences. To this extent they may be educated. They form habits and get the skill that comes from habitual action. They can compare situations and choose in accordance with experience. As the result of these powers, they reach conclusions in the presence of several conflicting appeals; conclusions which on the whole lend to their success in life. There are those who think these actions are *reflexes* even in the higher mammals, but it is clear that they are accompanied by "states of mind" comparable to what we call anger, fear, hatred, pleasure, and sympathy.

Students differ as to the existence of reasoning among animals. If we mean by reasoning the formation of abstract ideas, such as would be expressed among us by a

descriptive word, and the using of these ideas to reach an equally abstract conclusion, they doubtless do not reason. But there is probably no sharp distinction, even in the human mind, between reflex actions, habits, instincts, the utilization of memory and experience in the presence of concrete situations, and pure abstract reasoning. It is doubly difficult to make these distinctions in other animals.

They have some power of imitation, and while it is not so great as that of man, it nevertheless is an important feature in their behavior. The instinct of imitation makes for quicker and safer education.

FIG. 146.—Diagram of stomach of dog (A) and rat (B). After Wiedersheim.

342. Relations to Nature.—The mammals are practically cosmopolitan. The whales, the seals and the sea-cows live in the ocean. The moles and some of the rodents burrow in the ground; the bats fly quite as well as the birds; many live in trees, as the sloths and monkeys; and the great majority live on the solid ground. There are some 3,000 species. They vary in size from mice to whales. They use all possible kinds of food, and they are closely adjusted in many ways to the nature of their food. These adjust-

ments include, beside the digestive tract itself, the shape and size of jaws, the teeth, the tongue, the lips, the claws, and indeed the very nature and instincts of the animal.

The teeth are better developed and more differentiated in the mammals than in any other group. The three types are the cutting (*incisors*), the tearing (*canines*), and

FIG. 147.—Diagram of stomach of a ruminant. After Wiedersheim.

Questions on the Figure.—What is the significance of the term ruminant? Of what conceivable advantage is this form of stomach? What animals belong to the class?

the grinding (*molar*) teeth. Usually much of the habits and relations of the mammal can be told by a study of the teeth alone.

Many mammals are gregarious, going in herds or flocks, as is seen in seals, rodents, sheep, deer, wolves, monkeys, and man. This tendency is seen particularly in connection with food getting, polygamous mating, migrations, and defense.

343. **Relations to Man.**—The group is of especial theoretical interest to us, because it is the class to which we belong. It is furthermore the class of animals on which we are most dependent for the comforts of life. They furnish our beasts of burden, the bulk of our flesh foods, many of the materials for our clothing, beside a great number of miscellaneous articles commonly used by civilized peoples. Man doubtless could live on the earth without the aid of the mammals, but life would be a very different thing from what it is at present. If mammals have influenced man, he has even more profoundly influenced them. The great carnivorous animals that have been most unfriendly to man are gradually but surely disappearing before him. The greatest change which man has wrought, however, upon the class is through the domestication of those species which were at once useful and easy of domestication.

344. **Practical Exercise.**—The student should enumerate as many as possible of the materials used by man which have a mammalian origin, and determine the exact source of each. Where do the mammals live which supply these various materials?

345. **Leading Types of Mammals.**—Reference has already been made to the division of the group into three sub-classes—*monotremes*, *marsupials*, and *placentals*. The monotremes include only a few forms confined to Australia and the neighboring islands. The Duck-mole (Fig. 148) is one of these.

The marsupials are more numerous and comprise the native mammalian fauna of Australia. The kangaroo, a vegetable feeder, is the largest and best known of these, but there are numerous others with habits varying all the way from those of the rodents to the carnivorous life of cats and bears. The only native marsupial we have is the Virginia opossum (Fig. 149). Other species are found in South America. The marsupials are the mammals of a former geological age, and those on the earth now are to be looked upon as remnants rather than as a real branch of the modern mammals.

The following orders all belong to the placentals or true mammals.

The three most important orders are the hoofed mammals (as the cow, horse, etc.), the clawed or flesh-eating animals (as the cats, dogs, etc.), and the primates (to which the monkeys and men belong). Beside these there are four other North American orders of less importance: the rodents (rats and mice, etc.), the insectivorous mammals (moles), the bats, and the whales. The sloths and armadillos are lowly types found in the southern part of North America and in South America. They are known as *edentates*, or toothless mammals.

FIG. 148.—Duck-bill (*Ornithorhynchus anatinus*). Photo by Folsom.

Questions on the Figure.—What are the peculiarities of the species? What does the structure of its feet suggest as to its habits?

346. **Whales, Porpoises, and Dolphins (Cetacea).**—Because of their life in the water and their adaptations to it these animals are often looked upon as fishes. While whales include our largest animals, reaching 80 or even 100 feet in length, some of the species are not more than four to eight feet in length. They have little hair and their teeth may disappear or be replaced by “whale-bone,” which serves as a strainer to retain the small fish, and crustacea, etc, when the water is forced out of the mouth after a “catch.” The function which hair serves in

mammals, of aiding in the retaining of the heat of the body, is performed in whales by a thick layer of fat, or blubber, under the skin. The nostril is at the top of the head for convenience in breathing or "blowing."

FIG. 149.—Young opossum (*Didelphys virginiana*). Photo by Folsom.

Questions on the Figure.—Of what conceivable value to the animal is the prehensile tail? In what other groups of animals is the tail prehensile? What are the habits of the opossum? How is the species distributed on the earth? What are its nearest relatives? Where are they found?

347. **The Rodents (Rats, Mice, Rabbits, Squirrels, Beavers, and Porcupines).**—These are numerous in species

and widely distributed. (See Fig. 150.) They do not have canine teeth, but the incisors continue to develop in such a way as to maintain a sharp edge of enamel in spite of wear. They feed on vegetable diet chiefly, as nuts, acorns, grains, growing shoots, and are often attracted to stores that man has made. The rats and

FIG. 150.—The jumping rat (*Perodipus richardsoni*), adult male. Photo by Shufeldt.

Questions on the Figure.—What order of mammals is illustrated by this form? What explanations have been offered as to the cause of the light-colored belly and the darker back of animals? Of what conceivable advantage is the difference? How does the tail of this species compare with that of our common rat?

mice follow civilization and find harbors and food in the homes of men. Many of them burrow extensively, as the gophers, ground squirrels, prairie-dogs, ground-hog, beaver, etc. Most of them are more active at twilight or in the night. For this reason the smaller species furnish a large part of the food of owls.

348. **The Moles (Insectivora).**—This is a small group, consisting of moles and shrews. They are burrowing forms. The shrews are small and very like mice in appearance. They live on grubs and worms in the soil and not on the vegetation, as so many believe. They

FIG. 151.—Flying fox (*Pteropus*). U. S. Dept. Agriculture Year-Book, 1898.

Questions on the Figure.—What is the structure and arrangement of the wings in such a form as this? To what order of mammals does it really belong? Why is the common name misleading?

frequently tear up the turf, however, in making their tunnels and thus do injury to the vegetation. Their eyes are small and set deep, and are often quite rudimentary.

349. **The Bats (Chiroptera, Fig. 151).**—There are some 400 species of bats. They fly by means of a fold of the

skin, stretched between the fingers and from leg to leg. The bat is extremely sensitive to touch, and it is claimed that they are able to guide their night flights by this sense rather than by sight. They rest in caves and other dark places during the day, where they support themselves by means of the claws on the thumb of the arm and on the toes of the hind limbs. They feed on insects and fruits. One species is known to suck blood. The front legs are better developed than the hind ones, which is not common in mammals. They are somewhat gregarious in habits.

350. The Hoofed Mammals (Ungulata).—This order includes a number of large animals, chiefly herbivorous, that walk on their toes. The horny growth so common in the vertebrates at the end of the toes becomes broadened and thickened into a hoof. There are three subdivisions of this large group: (1) the even-toed types, in which the toes have been reduced to four or two; (2) the odd-toed types which have five, three, or one; and (3) those with a proboscis, or much developed nose, for grasping (as the elephant and the extinct mammoth and mastodon).

The even-toed forms include the *ruminants*, which have a complex stomach (Fig. 147), and after swallowing their food in large pellets they send it back to the mouth later to be chewed ("chewing the cud"). Here are included some of the animals most important to man, as the ox, the camel, the sheep, the goats, the deer, the giraffe, and all their kind. The non-ruminating even-toed mammals are the hippopotamus, the hog, the peccaries. In the language of the Bible they have the "cloven hoof, but do not chew the cud."

The odd-toed ungulates embrace the rhinoceros (three toed), and the horse, zebra, ass, quagga (one toe). The functional toe in the horse is the third or middle toe. The splint bones on the side of the lower leg of the horse are remnants of the second and fourth toes, which were functional in the ancestors of the horse.

351. **The Carnivora.**—Here are included some marine mammals, as the seals, sea-lions, walruses, and a large number of land animals with splendid strength and cunning. Their claws and teeth are sharp and curved and adapted to hold and tear flesh. They have jaws very powerful in relation to their size. Chief among these mammals is the *cat family*, including the lions, tigers, leopards, jaguars, panthers, and all the lesser cats. Others are the *dog family*, consisting of wolves, foxes, jackals, and dogs of many varieties; the *bear family*; the *weasel family*, minks, otters, badgers, skunks, etc.; the raccoons; the hyenas. They have been very successful forms, but for various reasons they are not holding their own against man. Some are being destroyed because they are dangerous to man; others because they attack the animals that man is safeguarding; still others because they have beautiful furs. Some are disappearing incidentally, as the wild animals upon which they habitually preyed are disappearing.

352. **The Primates (or Highest Mammals).**—These are the highest mammals, but there are included in the group some quite lowly animals. There are really at least five grades of these primates to be held in mind by the student:

1. The lemurs of Africa and Madagascar are small

monkeys of dog- or cat-like form, and stand intermediate between the true monkeys and the lower mammals.

2. The New World monkeys are of the broad-nosed variety and are distinctly lower than the next division. They are smaller and have long prehensile tails. They live in trees and include the marmosets or squirrel monkeys, the howling monkeys, and the spider monkeys.

3. The narrow-nosed dog-like apes of the Old World, which are quadrupeds, with fore and hind limbs about equal. They have tails and include the baboon, the mandrill, and the macaques.

4. The man-like apes of the Old World, which are tailless, stand more or less upright, and use the fore limbs as hands. These are the gibbons, orang-outang, the gorilla, and the chimpanzee. The gorilla is most like man in body, and the chimpanzee in intelligence. These four types of man-like apes live in southern Asia or in Africa.

5. Man (genus *Homo*) is more erect, but agrees in fundamental structure with the animals mentioned in four. He is now found over the habitable world; but the evidence seems to indicate that he originated in tropical or subtropical portions of the Old World, as did the higher apes. He is the only animal which writes zoologies.

353. **Practical Exercise.**—To what groups of mammals do the following animals belong: hairy ant-eater of South America; the manatee; the grampus; llama; the moose; the bison; guinea-pig; flying squirrel; tapir; lynx; the flying fox?

354. **Key to the Principal Orders of Mammals.**

Lay large eggs; no teats; merely a milk surface,

Sub-class Monotremata.

Examples: Duckbill, spiny ant-eater.

Bring forth young alive.

Young prematurely born and placed in pouch,

Sub-class Marsupialia.

Examples: Opossum, kangaroo, Tasmanian wolf, bandicoots.

Young retained in uterus until developed,

Sub-class Placentalia.

Teeth wanting or without enamel *Order Edentata.*

Examples: Sloth, armadillo, scaly ant-eater.

Teeth with enamel (wanting in most Cetacea).

Hind limbs wanting; digits not distinct. . . *Order Cetacea.*

Examples: Whales, dolphins, porpoises.

Hind limbs present; digits distinct.

Digits with claws.

Front limbs modified to form wings,

Order Cheiroptera.

Examples: Bats.

No wings.

Canine teeth wanting; incisors large and sharp,

Order Rodentia.

Examples: Rats, mice, beavers, squirrels, rabbits, gophers.

Canines and incisors present, small and sharp,

Order Insectivora.

Examples: Moles, and shrews.

Canines large and suited to tearing flesh,

Order Carnivora.

Examples: Seals; walruses; cats, dogs, bear, etc.

Digits with hoofs; molar teeth suited to grinding,

Order Ungulata.

Toes 5; incisors forming tusks; nose a long flexible proboscis *Sub-order Proboscidea.*

Examples: Elephants; mammoth and mastodon (extinct).

Toes less than 5.

Odd number. *Sub-order Perissodactyla.*

Only one toe on each foot (others mere splints),
Horse family.

Examples: Horse, ass, zebra, quagga, mule.

Three toes. *Tapir and Rhinoceros.*

Even number. *Sub-order Artiodactyla.*

Chew the cud; upper front teeth wanting,

Ruminants.

Examples: Camels, oxen, bison, sheep, antelopes.

Do not chew the cud; upper front teeth present.

Examples: Hogs, peccaries, hippopotamus.
Digits with nails; thumbs opposable... *Order Primates.*

Examples: Monkeys, apes, man.

355. **Topics for Themes in Zoology and English.**—1. Native American members of the dog family. Of the cat family. Of the camel family. Of the deer family.

2. The geological history of the horse family.

3. Discuss the individual and social habits of each of the following mammals: the beavers; the fur-seals; the otters; the elephants; the prairie-dogs; the rats.

4. Discuss the range of hair-like covering found in the group, from finest fur to porcupine quills. Discover the ways in which they are used by man.

5. What is the history of the introduction of rabbits into Australia? Can you cite any similar experience with rodents in this country?

6. Make a report on furs and fur-bearing animals. Is the permanent preservation of any of them possible? What steps are necessary?

7. An account of the whale fishery, past and present.

8. The varying degree of development at birth of the carnivores and the herbivores. Why the difference? How does the human infant compare with these at birth? The meaning of this?

9. Give an account of each of the following, making quite clear the meaning of the topic: ambergris; whale-bone; the ruminant stomach; ivory; the okapi; the vampire.

10. Discuss the various regions in the digestive tract of a dog or a cat. How does that of a sheep or cow differ from it? For what reasons?

11. What is the difference between claws, nails, and hoofs?

12. What is the nature of horns among mammals? Which bear them? In what various ways do they differ? Compare the mode of growth and structure of a cow's horn with that of the antlers of deer.

13. Make spring studies of the behavior of mammals.

CHAPTER XXVII.

CHORDATA: CLASS MAMMALIA (CONTINUED): MAN.

356. **General Statement.**—Man agrees with the higher primates in all the essential structures and functions. In many minor details, too, he resembles them. The form of the fingers and the flat nails; the number and arrangement of the teeth; the shape of the face, and numerous other superficial things might be chosen to show the likeness between man and the higher apes. It is agreed by zoologists that there is less difference of structure between man and the higher apes than between the apes and the monkeys.

In general, man agrees with all animals in all that is necessary to make an organism an animal; he agrees with all the vertebrates in the vertebrate characteristics; he agrees with all the mammals in their distinctive features; and finally he agrees with the primates in the qualities that separate them from the lower mammals.

357. **The Structural Distinctions Between Man and the Other Mammals.**—Man differs from the other primates in the fact that he is more upright in position. This brings about a greater development of the hind legs and the pelvic bones for support and leaves the hands free to serve the individual in ways other than locomotion. He differs also in the size of the brain and in the convolutions of it. The brain of the average man weighs from two to three times that of the gorilla, while the heaviest

known human brain is only twice as heavy as those of the lowest races of men. There is a corresponding difference in the shape of the head (compare Figs. 152 and 154).

FIG. 152.—Human skulls.—The one in heavy outline, with portions shaded, is a caucasian skull. That merely outlined (in dotted line) is of an Australian negro.

FIG. 153.—Skull of young orang-outang (dotted outline) superimposed on that of young child.

The great toe cannot be opposed to the other toes as in the case of the apes (Fig. 158), or as man can oppose his thumb. There is freer motion of the big toe, however, in

newly born babes than in adults. The canine teeth of man are somewhat less developed, and the body covering of hair is not so pronounced. These differences, except that relating to the brain, are of minor importance.

FIG. 154.—Skull of adult orang-outang.

Questions on Figs. 152–154.—Enumerate the similarities and the differences apparent in these skulls. In what respects is the negro skull intermediate between the orang and the caucasian? Is the difference between the orang and the human greater in youth or in the adult? What is the probable significance of this? What are the zig-zag lines in some of the figures? What is the meaning of the shaded area above the cheek-bone and back of the eye? How does the lower jaw in the higher races compare with that of the lower? The meaning of this?

358. Functional Distinction Between Man and the Other Mammals.—While the structural differences are not sufficient to remove man from the group of primates, because they are relatively insignificant in themselves, the powers and activities and modes of life that have arisen from these do serve to place man clearly into a

FIG. 155.—The outline of the brain of an orang-outang. Adopted from Gegenbauer and Vogt and Gratiolet. Front portion, F to O, cerebellum; C, cerebrum; M, medulla and spinal cord; F, the frontal lobe; P, the parietal lobe; O, the occipital lobe; T, the temporal lobe; R, the fissure of Rolando; S, the fissure of Sylvius.

FIG. 156.—Brain of Hottentot woman. From Mill's "Text-Book of Animal Physiology;" Copyright D. Appleton & Co. Lettering as in Fig. 155.

group of his own. These great improvements in powers have accompanied and are in some measure due to the gaining of the upright position and to the use of the hands as the instrument of the brain and to the development of spoken language. These three things—the enlarging brain, the free hands, and the growing language—

FIG. 157.—Brain of Gauss, the mathematician. From Mill's "Text-Book of Animal Physiology;" Copyright D. Appleton & Co. Lettering as in Fig. 155.

Questions on Figs. 155–157.—Identify and compare the cerebrum in these three brains. What are the chief differences? Compare the mass in front of the *fissure* of Silvius (that is, the *frontal* lobe), in the three. What is the reason of the connection between the numerous convolutions and mental development? Which increases more, the cerebrum or the cerebellum, as we ascend the scale? The meaning of this?

would tend to train and improve one another. The brain working through the hands, means the making of implements, of dwellings, and of numerous forms of mastery over nature. The brain working through language and in the more intimate parental relations brought about by homes, makes possible education and the training of the

young in the discoveries of the race. The use of language has been the great instrument whereby the power of abstract reasoning has been developed, and this has produced the great increase in size and complexity of the brain.

359. Mental Life of Man, Habits, Instincts, Reason.—Fundamentally, the mental life of man, no less than that of the lower animals, is the function of the brain and its accompanying systems of organs. Like that of all the other animals, much of man's life and activities is made up of habitual actions that have been acquired through trial and experience and the crystallizing of these through memory. Much of it, quite as really as in the lower animals, is of those more mysterious impulses (instincts) that we do not get by our own experiences, but which belong to our make-up in some way as an inheritance from the past of our ancestors. The mind of man, working upon these experiences and internal feelings and using language to make clear to others his states and to convince them of his conclusions, has reached what may well be regarded as the highest human power—that of abstract reasoning; of saying, (1) this is true; and (2) *this* is true; (3) *therefore, this* is true. The study of this feature of Zoology is known as Psychology. The lower animals have their psychology as well as man, but it is not so far-reaching nor complex.

360. The Social Instincts and their Result in Man.—In the course of our studies we have found many animals that recognize their kind and more or less definitely associate with them. This reaches a very high plane in the bees and ants. Similar social life is to be found in all the primates, but it is not so well organized as among the ants.

In man, even in primitive man, these social instincts

are well shown. They are complex, just as in the bees. They involve the mating instinct, the care of young, the storing of food, the finding of shelter and safety, as well as the instincts of general gregariousness found in many forms. These associative instincts lead to the home, to marriage, to the family, and later to the larger family or group made up of the immediate kindred. Thus tribes

FIG. 158.—Hand and foot of chimpanzee. From Home and Country Magazine.

Questions on the Figure.—Which is hand, and which foot? In what particulars do they differ? How do they differ, respectively, from those of man? In which is the difference from the human condition greater? What is the functional meaning of these differences?

and clans and nations come to be bound together. It is not claimed that this is the only way in which human societies may be built up, but there can be no question that it has been so built up in many instances.

In this growing complexity of society, customs, regulations, and special institutions to accomplish certain ends spring up just as the division of labor arose in the bee

colony. These demands of society gradually mould the individuals and their social ideals. Next to the hand and to language, probably the social relations of man have been important in training his mind and developing his brain. It is easily seen that the higher qualities of man, as sympathy, love, unselfishness, heroism, and self-sacrifice, are the qualities of mind, or "heart" as we sometimes say, that would be given prominence in the home and the other really social institutions. The study of man and his social life is known as *Sociology*.

FIG. 159.—Diagrammatic horizontal section through the right eye of man. The line *ap* is the axis of vision. The optic nerve leaves the eye toward the middle of the head from this line. *a. c.*, central artery; *a. h.*, aqueous humor; *b*, blind spot, the entrance of the optic nerve; *c.*, conjunctiva; *ch.*, choroid layer of the eyeball; *cl.*, crystalline lens; *co.*, cornea, the transparent portion of the sclerotic coat; *fo.*, point of clearest vision; *o. n.*, optic nerve; *r.*, the retina, or sensitive coat of the eye; *sc.*, sclerotic coat; *v. h.*, vitreous humor.

Questions on the Figure.—Which is the essential sensory portion of the eye? Which parts are supportive and protective? Which parts are concerned with bringing the rays to a focus on the retina? Why is an image formed on the retina of an object in front of the eye? Consult your physics and determine the principles.

361. Education and its Place in Human Development.—

Education is, in general, the development of the individual in such a way that he will be able to adjust and to readjust himself rightly, in the light of his whole nature, to the essential factors of his environment. This adjustment has come slowly in the race, step by step in the experience of each. Individual education in mankind is an effort to give the child a short cut to the best that has been discovered by the race in its history, so that it will not be necessary for him to get it all by experience. Language is again the vehicle that makes this possible. Some education is possible through sight and imitation of parental actions, and there is probably a certain amount of such education in many of the lower animals. Confidence in the parents, imitation, and curiosity are important individual instincts underlying the education of the child. The long dependence of the child on the parents, the close relations of the home, the warmth of sympathy in the parental feeling, all enter in furnishing the motive and the opportunity for the training. That this education is efficient is shown by the fact that the individual youth in a period of twenty or twenty-five years may be brought to a knowledge of the most important experiences of the human race; of the great implements of human progress, as spoken and written language, knowledge of nature's laws, and the relations of numbers; and of the great, partly natural and largely artificial, structure which we call human society, as well as of the modes of behavior necessary to meet its demands.

These have required thousands of years to build. Many of them have not become instinctive. It is the triumph of human attainment that so much can be imparted in so short a time.

362. **Man's Relation to Nature.**—There is nothing in what we can learn about man that suggests that he is not just as dependent on the natural laws of his own being and of the environment about him as any other animal in the animal kingdom. He starts in the same humble way, as a single cell; he has the same powers of growth and development, but he must have conditions favorable to them. To-day is always the child of yesterday, just as with the other animals. He has the like diseases; he is affected with similar parasites; he has enemies among the animals just as is true of the others. Equally, he depends on them for his food. The same struggle for existence and the survival of the fittest that we find in all of life can be traced in much of human history.

Man, however, has made a mastery of nature which no other forms have been able to do. Probably through his wits and his supple hands, rather than by strength, he held his own against the powerful mammals which preceded him on the earth. By the same means, but in increasing degree he holds that mastery to-day. Through his wits, again, and his wonderful hands he has managed to use the inorganic forces of nature as no other animal has or can do. Through his wits, and most of all through his growing sympathies and unselfishness, he bids fair to build up a society, based on friendship and love, which will substitute cooperation for competition in the broader relations of life just as it has already done in the home itself.

363. **The Artificial Surroundings of Man.**—In what we call civilization man has so controlled the natural conditions as to create for himself an environment which is greatly different from that under which man first

lived. Clothes, houses, cities, fire, seasoned foods, stimulants are terms which suggest some of these artificial elements that have entered into man's life. Just what their final effect will be on the body and mind of man no one can tell. Many of the most terrible diseases to which man is subject are the diseases of civilization. That his wits will continue to enable him to meet the new problems which he brings on himself, as he has met the natural ones, we may well believe. But unquestionably we must realize that his greatest task is to use his increasing mastery of nature in meeting the new difficulties which his own complex and artificial civilization is bringing upon him.

364. **The Age of Man on the Earth.**—There is no sure knowledge of when man, in his present form, first appeared on the earth. It is known that man lived in Europe in the later portion of the Ice Age, and quite probably earlier. His implements of stone are found along with the remains of such animals as the cave-bear and mastodon and man-like apes, either extinct now or found only in tropical regions. The oldest of these human remains are found in southern Europe and in northern Africa. We have signs of the gradual improvement of his stone implements from rough to smooth; the introduction of other material as bone and, later, copper, bronze, and iron. It is only after the thousands of years of this primitive, unrecorded history that we come to the history of such well separated nations as those of the Euphrates and Nile valleys, whose monuments and inscriptions are believed to take us back 6,000 years or more.

365. **The Principal Types of Men and Their Distribution.**—It is not perfectly certain that all the men of to-day

should really be placed in one species, although if we follow them back far enough they probably had a common origin. The pigmies of Africa or the Negritos of the Philippines are more removed from the Caucasian than is true of many separate species of the wild animals, and the differences are both characteristic and constant. The varieties of men are innumerable, but there is a tendency to group them all under three main heads which we may call: (1) The white or Caucasian; (2) the yellow or Monogolian, and (3) the black or African. To these are often added the red or native American, and certain island and peninsular types that do not agree very well with any of the others. The most striking external differences are: The color of the skin, the structure and appearance of the hair, the form of the nose (which is also used in distinguishing the apes), the form of the jaw and skull, and the character of the language. Under the Caucasian race are included the wavy-haired peoples, as the chief European peoples, the Egyptians, the Jews, the Arabs, the East Indians, and the peoples of the Caucasus who give the name to the race. The Mongolians would include the straight-haired, yellowish and brownish varieties, as the Chinese, Mongols, Manchus, Tartars, Japanese, Turks, Finns, and possibly the native American tribes, as Esquimo, Indians, and the South and Central American peoples. The black or negro race includes many tropical forms dark in color and with wavy or frizzly hair. Such are, the dwarf Negrillos of central Africa; the Hottentots and Bushmen; the Negroes of the Nile, of the Senegambia, and of Guinea; the Caffres, Zulus, and other tribes of the east coast; and many others.

The great number of these human races, or varieties, is an evidence of the long time man has been on the earth

and of his adaptability. They have arisen and have been increased by the natural tendency to vary, by the effects of climate, by migration and isolation, by interbreeding, by conscious selection of mates in accordance with local standards of attractiveness, and the like. This phase of zoology is known as *Ethnography*.

366. **Topics for Themes in Zoology or English.**—1. Study the effects of tropical conditions on the human race, as judged by the races of men now found there: Effects on skin; on physical and mental states; on industrial and social life.

2. Study similarly the effects of life in the temperate zones. What is the value to man of the alternation of summer and winter, in encouraging thrift and foresight; in the permanency and character of homes, etc. The effects of these things on stability of government and of social institutions generally.

3. Similarly study the conditions of extreme cold, as seen in the life of the Esquimos, Finns, Laplanders, and the like.

4. Where were the highest examples of aboriginal civilization on the American continent when it was discovered? Describe.

5. Describe the steps whereby the clan, the tribe, and the nation may be built up with the home as the starting-point. What new personal qualities are called for and cultivated by the social life of the tribe?

6. Illustrate the effects of the physical geography of the earth on man's life and history. Examples: Egypt; Greece; Palestine; the Mediterranean Sea; the depression formed by the Hudson River and Lake Champlain; the Allegheny mountains; effects of continents on races.

7. On the whole, does it seem that man has been subject to the same influence by external conditions which we have found in the lower animals? Illustrate.

8. Human migrations. Cite some of those that belong to recorded history and look at their causes and results.

9. What is the zoological character of mixed or hybrid races of men?

10. What is the human population of the earth estimated to be? How is it believed to be distributed among the leading races? Which is growing with greatest rapidity? What reasons can you assign?

CHAPTER XXVIII.

DISTRIBUTION OF ANIMALS ON THE EARTH.

367. **Definition.**—Most of us remember the pictures in our old geographies in which animals of various kinds were crowded together in the zones—frigid, temperate, and torrid. Most of us too have personal knowledge of the fact that in our own locality the animals living in the ponds and running streams, and meadows, and caves, and forests differ among themselves. Again, we expect to find pretty much the same kind of life in the similar ponds even though they may have no connection. The discussion of these questions of the place of animals on the face of the earth, whether on a small or large scale, belong to this subject of the *distribution of animals*.

368. **Local Distribution.**—Every student should make a study of the local distribution of the wild animals of his locality. This is often done by means of a much enlarged outline map of the township on which the general topographic features, as roads, streams, lakes, forests, and the like, are outlined. Areas can be indicated as swamp, or prairie, or hills, or woodland, or otherwise. Successive classes of students can keep the results of their findings here in such a way that it will be in course of time a good guide to the local *fauna*, or total animal life of the district. It will tend to show how certain animals are confined to limited areas and others wander more widely.

369. **Fundamental Faunas.**—There are certain fundamental conditions which determine life, irrespective of the place on the surface of the earth. These conditions are more important than temperature, or latitude, or altitude, or the differences between forest and prairie. The faunas dependent upon these conditions are the marine or salt-water faunas, the fresh-water faunas, the land faunas, and the aerial faunas. The pond life of central Africa is more like the pond life of America than the life in the pond is to that on the land three feet away. The greatest of all differences are between the life in water and the life on land. These differences depend primarily upon the method of breathing.

On top of these great features, which determine the life, are others of less importance. For example, the animals that live at the margins of the seas differ considerably from those out on the high seas; and both of these are very different from those at the bottoms of the deep seas. Similarly we have seen that the varying conditions on land produce their effect on the nature of the life.

370. **The Course of Development of Faunas.**—If the evolutionary view is correct, animals have not always been distributed as they are to-day. This condition is itself an evolution through the ages. It is the belief that the first life was aquatic, and marine rather than fresh water. Whether it was out in the high seas or near to shore is a matter of speculation. From this original position organisms spread and became adjusted to the other marine conditions. Gradually some became adjusted to brackish water at the mouths of rivers and finally to the rivers themselves. From the sea or from

the rivers, or from both, the land became populated by animals which wandered away from the water, by burrowing into the moist earth or otherwise, and gradually acquiring the air-breathing habit. Last of all, the flying types arose from those that had learned to live on the land.

371. What Determines the Distribution of a Species of Animals over the Earth?—If an animal is a marine animal will it come to live in all the seas and be successful there? If an animal lives on the land will it occupy all of the land of the earth equally or even all the continent on which it lives? In answering these questions the following facts must be borne in mind:

1. All animals tend, by means of their powers of multiplication and motion, to scatter from the point at which they may start and to possess the territory. Unless something prevents, this would lead ultimately to the whole earth being covered by all species.

2. All animals are specialists, in some degree, in the way of habitat. They flourish less well in some localities than in others, and less well than some other species will.

3. A region, in which for any reason a given species does not flourish, becomes to that extent a *barrier* to its scattering. To forms that frequent marshy land, mountains and plains and rivers might prove a barrier, keeping it out of all lands beyond.

4. Animals that do succeed in getting over barriers or getting into regions somewhat different from those to which they are adjusted, must meet the competition of the animals already on the ground, and they must change in such a way as to become adjusted to the new conditions of life. In doing this they may become so

changed as to form a new species of animals, differing permanently and strikingly from their ancestors. It is believed that this is the way in which many new species of animals have been formed.

372. The Means of Dispersal.—One of the chief ways in which animals are dispersed from any given point is by means of their own powers of locomotion as they go about in search of food and of mates, or to escape such temporary discomforts as winter, drouth, famine, and the like. Animals differ very much in their powers of locomotion and hence in readiness of distribution. Animals that live in water may be carried about, particularly in the egg or larval stages, by the waves and currents. In a similar way, many land forms and minute pond animals that can resist drying, either in the eggs or in the adult, may be swept far and wide by the winds. Many small forms are carried by other animals, as in the case of snails that may be carried from pond to pond, either in egg or adult, on the muddy feet of water birds. Parasites are carried by their hosts. Man has carried many species of animals over the surface of the earth in his ships and other vehicles. Illustrating this are sparrows, rats, mice, cockroaches and many other insects.

373. Barriers to Dispersal.—The chief barriers that stand in the way of a general and universal distribution of animals are: differences in temperature; drouth, as is seen in deserts; water, in the case of land forms, and land, for water forms; salt-water for fresh-water types, and fresh-water for salt-water types; physical barriers, such as mountains on land and falls in rivers. These barriers act differently in different cases. Only wide oceans or deserts or very lofty mountains are barriers to

flying forms, whereas a very narrow bit of sea-water would be a complete barrier to fish or other animals living in a river emptying into it. Some forms have a very narrow range of temperature, as the polar bear; others may range widely without feeling the limiting effects of temperature, as man.

In general, the barriers that count for most in determining the great world faunas are temperature as determined by latitude; the oceans to land forms; and the continents to ocean forms. The continents and oceans divide the earth roughly from north to south; the temperature zones divide it from east to west.

374. The Principal World Areas of Animal Life.—The result of these barriers has been to separate the earth into *realms* which are usually indicated about as follows: (1) the *Nearctic*, including temperate North America and Greenland; (2) *Neotropical*, including Mexico, Central America, and tropical South America; (3) the *Palæarctic*, including Europe and northern and central Asia; (4) the *Indo-African*, including tropical Asia and Africa; (5) *Australian*, including besides Australia the islands of the south Pacific and Indian oceans. In addition to these are certain oceanic islands, such as Madagascar, which have been so long isolated as to have faunas very different from the nearest continents.

375. Practical Exercise for Library.—The student should by reference to all sources find what are the most characteristic types of the higher animals, at least, of these five geographical regions. What are the conditions that are believed to have produced the peculiar differences between them and those nearest them? Treat especially the fauna of Madagascar and of Australia.

376. Topics for Themes in Zoology and English.—1. What is the original home and natural distribution of the

following domesticated animals: horse, chicken, turkey, pigeon, ostrich, reindeer, camel, hog? Of these wild forms: panther, jaguar, tiger, kangaroo, seals, salmon, chimpanzee, anaconda.

2. Justify the statement that Australia is biologically a belated continent as compared with the others.

3. What arguments have been offered in support of the view that the sea near the shore is the original home of life? What for the view that life commenced out in the high seas?

4. Discuss water as a means of dispersal, and as a barrier to dispersal of animals. Give illustrations.

CHAPTER XXIX.

THE EVOLUTION OF ANIMALS.

377. In the preceding pages the words evolution and development have been used frequently, but no effort has been made to define or justify them. In all that has been said it has been assumed that the animals now on the earth have come to their present condition of variety and complexity by natural growth and development, rather than by outright creation as we find them now. This has been assumed, not because there can be any complete demonstration of the view, but because it is more in accordance with the facts as we find them than any other theory which has been offered.

The student is now in a position to study the question of evolution more broadly, and to appreciate a more full statement of it.

378. **The Meaning of Evolution.**—There is a good deal of haziness in the thought of people generally as to just what the zoologist means by evolution. Evolution is not in any sense a cause; it is a term for a *process*, for the way in which present conditions have come about. Briefly, the most important elements in the thought of evolution are *gradualness* and *naturalness*. In more detail, the following features may be said to belong to the idea of evolution:

1. All life, so far as we can know, has come from pre-existing life. This year's animals are descended from

those of last year; they from those of the year before, and so on back.

2. All animals are subject to change. Offspring are never just like the parents. If given time enough animals may thus change in any degree. New species may come from old in this way.

3. The animals of the present time are descended from simpler, more generalized ones; and these from still earlier types. So even the most complex animals of the present have arisen ultimately from ancestors as simple as the simplest.

4. All animals have fundamental likenesses. Some are more alike; some are less so. The fundamental likenesses mean *kinship*.

5. The process of life is gradual rather than sudden, although the rapidity of it may differ at different times; it is natural rather than supernatural; it is subject to the same laws of cause and effect which operate in chemistry and physics, and is not lawless and arbitrary.

6. On the whole, the life-processes result in a closer and more perfect adjustment of organisms to one another and to the organic environment.

379. **Evidences for the Development Theory.**—Biologists generally are agreed as to the *fact* of evolution, and there is no longer any direct search for proofs of the belief. Any disagreement among them is in respect to the manner in which evolution has come about, and the present search is for the causes and the factors which produce it. Many people, however, look with some suspicion on the theory. For this reason the student should have before his mind some of the classes of facts that have convinced biologists of its truth.

380. Variability as an Evidence.—The changeableness of organisms is the fact that makes it impossible for the biologist to deny evolution. Every day we see differences in organisms of the same species, which differences have been brought about by differences in the surroundings, by the behavior of the organisms themselves, by cultivation by man, or by something inherited from their parents. We know that man can take advantage of these differences and can select certain types; can cultivate and select again in such a way as to get, in a few generations of cultivation and breeding, animals strikingly different from those with which he started. After a certain time these new forms seem to breed reasonably true, and a new race is said to be established. In this way the different breeds or varieties of dogs, pigeons, chickens, and many other domestic animals have apparently arisen. This is not merely a proof of evolution; it *is* evolution. Any one who believes in this is an evolutionist by just that much.

There can be no reasonable doubt that just this kind of thing is happening in nature, without the help of man. It cannot take place, however, so rapidly as when man deliberately aids the process, by artificial selecting and breeding according to his preference, and then eliminates those that he does not want. It often happens, both in nature and in cultivation, that large variations ("sports" or "mutations") appear suddenly, and breed true in succeeding generations. These marked variations are not so frequent as the slighter ones, but seem to be more persistent when they once appear.

381. Evidences from Geographical Distribution.—In the wild state, the changes in animals are too slow for us to detect, within a human generation or so, that there has

been any change in a species; yet we do have some evidence on a broader scale which is of a nature quite similar to that in the last section. In the way in which animals occur on the face of the earth a great many interesting factors enter, and it sometimes happens that we get some good indication of the long-time effects of variation. Sometimes we find two forms of plant or animal flourishing in two regions that are separated from each other by some kind of a barrier which does not allow them to pass back and forth and thus to mingle. These forms are in general similar, and yet are constantly and recognizedly different. Sometimes we can find that these two regions (b and c) have been stocked from some third region (a), and that both varieties are apparently descendants of the same ancestors. Indeed, we may be able to find forms of all grades connecting "a" with "b" on one side, and other intermediate types connecting "a" with "c" on the other side. In cases like this, which are by no means infrequent, it is believed that "b" and "c" have migrated into their respective regions and in becoming adapted to their new condition of life have so evolved as to become different from their parent stock and from each other.

In a similar way, but on a much larger scale and in a form too complex to make clear to the beginner, we find evidences of change and development in the animals of the great continental and other natural divisions of the earth.

382. Evidences from Geological History.—In the rock strata of the crust of the earth we find abundant plant and animal remains in the form of fossils. In the most recent strata we find remains similar to the species of the

present time, whether of mollusks, of fishes, or of mammals. The further back we go in the earth's history the less similarity we find between the fossils and the present-day life. The earlier strata show only invertebrate remains; later the fishes appear, although much simpler and more primitive than the fishes of to-day. Later still appear amphibians, reptiles, mammals, and birds; and last of all man's remains.

The conditions are just what we should expect if life appeared on the earth in its simpler forms and gradually, by evolution through the ages, became complex and modern.

These things are not only true in a general way, but have been found to be true of the special types of animals. For example, the fossil remains of modern horses have been found in recent geological strata. The modern horse has only one toe on each foot and walks on the end of that toe. He has, however, some splints on either side of this digit which point us to the history of his toes. In the geological age preceding the present we find the remains of an animal clearly like the horse, in which these splints are larger and show more nearly the structure of normal toes. By tracing the conditions backward in geological times, links have been found which connect the skeleton of the horse of the present day with an animal of the *Eocene* period, which had four toes on the fore-feet and three toes on the hind feet and was little larger than a fox. These steps are so complete that expert students of fossils do not hesitate to regard that we have a fair knowledge of the ancestry of the horse for perhaps millions of years. Similar series of gradual changes are shown among many species of fossil animals, as mollusks, insects, fishes, birds, mammals.

All this is entirely without explanation if animals have not been subject to gradual evolution through the ages.

383. Evidences from General Similarities of Structure.—

In studying animals we need to keep in mind not merely the varieties and dissimilarities which we see arising, but the underlying likenesses as well. This underlying likeness of structure is really an evidence of relationship; which is another way of saying that animals, in spite of their differences, are apparently descended from a common stock. If, for example, we examine the offspring of a given pair of parents, as a litter of kittens or of puppies, we expect these individuals to be more alike in behavior, in disposition, and structure than will be the same number of offspring of totally different parents. This likeness is a sign and measure of their kinship. Two spaniels or two newfoundlands are more like each other than either is like to any other breed of dogs. The greater similarity is again the sign of their greater kinship. But the spaniel is more like the newfoundland than either is like the wolf, for the spaniel and the newfoundland probably belong to one species (*Canis familiaris*) and the wolf to another (*Canis lupus*).

The wolf and dog are more alike, and hence closer akin, than either is to the members of the cat family. The dogs and wolf belong to the genus *Canis* and the cats to the genus *Felis*. This is the way we express their degrees of difference. But in turn the dogs and cats are much more similar to each other than they are to the horse and cow. Because of this similarity in structure and behavior, the dogs and cats are classed together as *carnivores*, and the horse and cow together as *ungulates*.

With all their differences the carnivores and the ungulates have many fundamental points in common. They are all warm-blooded, covered with hair, have mammary glands, carry the young in the uterus attached by a placenta. Hence they belong to the sub-class *placentals* and to the class of *mammals*. They have similar parts to their skeletons, similar arrangements of the principal muscles, similar structure of the brain and central nervous system. Thus it might be shown that the newfoundland and the spaniel are similar to all the vertebrates, and finally to all the animals.

If the similarities of structure in a litter of kittens is a sign of kinship, we may equally believe that the similarities between the dog and the cow are also evidences of kinship; and that their differences mark a gradual evolution from a common stock in special directions and in adjustment to special modes of life through long ages of time.

384. Evidences from Rudimentary Organs.—It often happens that some animals possess organs in only a slight or rudimentary way, which in other animals are well developed and useful. In the rabbit, for example, there is a pouch called the cecum at the junction of the small and the large intestine. It is several inches in length, well supplied with glands, and probably of considerable value in digestion. In many mammals this structure is much reduced, and in man it is only found as a "vermiform appendix," which certainly has no such value as it has in the rabbit, and is thought by many physiologists to be a positive menace.

Similarly, in many mammals there are certain muscles by which the external ear is moved and directed so as to

catch the sound waves. In man these muscles are so reduced as to be of no value. Most animals have many rudimentary remnants of organs which are useful in other apparently related animals. It is said that man alone has several hundred such rudimentary structures. The rudimentary eyes of fishes and crustacea in caves, and the almost or entirely reduced organs of many parasites are mute testimony of the loss of organs once useful, through changed life conditions. In other words, *vestigial* organs are also evidence of evolution of animals into adjustment with the surroundings.

385. Evidences from Embryology.—The study of embryology—the course of life in the individual—has probably furnished us the most suggestive evidence of the evolution of animals. The main facts, and the use that has been made of them in reaching our conclusions, may be expressed in a few brief statements. The student must go to more extended texts for the complete handling of this complex but most interesting subject.

Some important facts of individual development are:

1. Each individual animal (with certain exceptions in non-sexual reproduction), no matter how high in the scale of life, starts its life as a single cell, similar in many respects to the permanent single-celled protozoans, except that it has the power of developing rapidly into its own peculiar species. (See Fig. 160, 1.)

2. All higher forms agree likewise in the next step of their development, which consists in the division of this single cell into a simple mass of cells. This is known as the *morula*, which is not unlike the adult, and highest stage, of such types as *Eudorina* and *Volvox* (colonial protozoa, Fig. 160, 2).

FIG. 160.—A diagram to suggest the way in which individuals of the different phyla have parallel development for a while, and later diverge in their own particular way. For example, an *Amphibian* begins life as a single cell, similar to the simple protozoa (1); later it forms a mass of cells similar to some of the colonial protozoa (2), in forming a gastrula (3) it is going through a stage similar to the *Hydra*, which is a kind of permanent gastrula. Amphibians run parallel to the fishes in development, in the formation of a body cavity (4), in forming segments (5), in development of notochord (6), in the presence of gills in early life (7); but part company with the fishes in the fact that they lose the gills and develop lungs (8).

Questions on the Figure.—Trace out other instances of parallelism until the purpose and meaning of the diagram become clear. Then find other facts with respect to development of animals and show how the diagram cannot do justice to the whole truth. Compare diagram with text, sections 385 to 387.

3. Practically all the higher animals pass next through a stage in which the cells become differentiated into two layers, more or less well defined and arranged in a kind of double sac—ectoderm on the outside and entoderm on the inside (see Fig. 20, A4). This is known as the *gastrula*. Animals like the adult *Hydra* (Fig. 46) are really a kind of permanent gastrula—somewhat modified in form to be sure, but a gastrula nevertheless.

The facts thus far stated may be taken as suggesting the following conclusions:

1. All organisms, even the highest, begin life at essentially the same point; that is, as a single cell. This similarity of individual origin indicates their fundamental kinship and similarity of racial origin.

2. The development of all the forms above the protozoa is parallel for at least a brief period; that is, through the morula and the blastula stages (Fig. 20, 3 and 4). This parallelism of development added to the similarity of origin points even more strongly to their kinship.

3. There is tendency for some forms to drop out of the race and to become permanently fixed about certain of these stages; as most protozoa at the single-celled stage, *Volvox* at the morula stage, and sponges and hydra at the gastrula stage. Others go on and introduce new steps of differentiation before reaching their adult development (Fig. 160: 5-9).

386. Careful study of the later stages of development of the higher animals gives us further illustrations of these truths and enables us to state even more broadly the principles deduced above. For example, we find that insects have a parallel course of embryonic development in which the great body of insects agree (Fig. 160). The

same is true of the vertebrates. One insect agrees with another insect in the mode of its development more nearly up to the complete adult character than an insect will agree with an echinoderm, or either with a vertebrate. In a similar way, all vertebrates have a course of development parallel for a longer time than they parallel any other group (Fig. 160: 6).

Furthermore, the same principle applies to the subgroups of the vertebrates, or of any other branch. The vertebrate development begins to differ from the insect development lower down than the divergence of the reptiles from the birds, or the mammals from the fishes (Fig. 160: 8). The parallelism between birds and reptiles ends earlier than that between one type of birds and another, or between man and the other mammals. Finally within a species, as of grasshoppers, of reptiles, or of rabbits, the course of development of different individuals continues identical through to the mature form. It is just those forms that seem most similar in structure (section 383) in which the embryonic development is most nearly identical. The two forms of similarity, structure and embryology, strengthen the idea of real kinship. Hence we have reached the conclusion that all parallelisms in the fundamentals of individual history marks some degree of relationship. The longer and more profound the parallelism the closer the relationship. A careful study of the diagram (Fig. 160) will serve to make this point more clear.

387. The Biogenetic Law.—Out of such considerations as these has come one of the most important and far-reaching laws that the biologists have ever stated. It is as follows: "Each individual animal, in passing from

the egg to the adult, repeats in an abbreviated way, in a few days or years, many of the steps taken by the race to which it belongs in its evolution from its single-celled ancestors to its present condition." Put briefly, it reads: *Individual history is a brief recapitulation of race history.*

Why can the individual egg cell of a frog, in a few months, pass through a morula, a blastula, a water-breathing legless fish-like stage, and into an air-breathing, four-legged adult? Because its ancestors were first single-celled animals, and through millions of years and countless generations gradually developed first into a mass of cells, later into a gastrula-like stage, and later still for long ages breathed by gills, like the fishes, and last of all became what they now are—water-breathing tadpoles with the power to breathe air in the adult life.

Because the history is so much shortened, only some of the more profound stages are recapitulated, and the advances of the race in thousands of years are compressed into moments in the individual history. Furthermore, each species has introduced idiosyncrasies that belong in no way to the race. For these reasons the general truth of recapitulation must not be applied too literally or widely.

388. The Principal Factors Entering into Evolution.—As was indicated earlier, biologists no longer question the fact of the evolution of the animal kingdom. They are now seeking to find the principal elements that are bringing about this result and how they work in the process. We doubtless have not found all the factors; those mentioned below are certainly some of the more important.

389. Variability and Variation.—It is clear that there could be no evolution if organisms could not change or

vary. All organisms vary. Variation suggests two or three things: (1) An animal may differ from day to day as the result either of its own activities or of the action of the environment upon it; (2) it may differ, at any stage or condition of its life, from what its parents were at the corresponding stage; and (3) it may differ also from its brothers and sisters even at the same stage of life and under similar conditions. Some of these changes are evidently caused by conditions outside the organism; others by internal conditions. These changes make evolution possible. Whether all these classes of changes enter equally into evolution we cannot say. One of the most important questions to the modern biologist is this: "What produces the variation actually found in individuals of a species, and to what extent are these variations due to internal or to external causes?"

390. **Heredity.**—While variation is necessary and produces some evolution of the individual, it does not insure racial evolution. Evolution of the race cannot take place unless, in some way, the individual variations are transmitted and accumulated. Heredity, the power to transmit new variations as well as the older characteristics, is therefore an agent in evolution. It does not follow that all new characters that an animal gets are subject to transmission; but without some means of passing variations from parent to offspring no evolution is possible.

391. **Isolation.**—If new variations occur and these variable forms are left to cross freely with relatives that have not varied, there is a tendency for the new quality to be "swamped" or buried. In order that variations that can be transmitted may be kept pure and in a position

to produce permanent and separate new stock, it is at least advantageous that the newly varied animals be isolated from the conservative, less variable relatives. This may come about through *geographical isolation*. A barrier, such as a mountain range or an arm of the sea, may come to lie between two kindred stocks in such a way that their special variations and adjustments may be kept pure, and thus new species are made possible through the isolation of varieties. This has doubtless been of the greatest importance in the history of animals on the earth.

It is also known that a similar result, in keeping strains separate, is sometimes obtained even when some kinds of variants are crossed freely with their parent stock. A certain definite per cent. of the ultimate offspring, in such crosses, will show unmixed the particular characteristics of each of the parents. That is to say, a part of the offspring will be pure, like one parent; and another part will be pure, but like the other parent. It appears as though the qualities of the original parents are kept apart and pure (*isolated*) in the union of the germ cells themselves, without geographical isolation, and are transmitted unchanged to the next generation. The student will find this subject discussed in the reference books under "Mendel's laws" of heredity.

392. **The Environment.**—Assuming that variations occur and make evolution possible, and that heredity enables these variations to pass from one generation to another and thus to accumulate, and that isolation keeps the various individuals from evening up and thus destroying their variations by inter-crossing, it still remains to find the factors that have determined and guided the

actual course of evolution in any given instance. Why has development taken the course it has?

Theoretically there might be an inherent tendency in living matter at the beginning to vary or evolve in a certain direction. Biologists are not agreed upon the existence of such a tendency. On the other hand, the environment—meaning the total external conditions of the life of organisms—may guide or direct the course of development. Any guidance must come from the one or the other of these sources.

The environment may act in either of two ways to mold evolution. We have seen in the first place that the environment does act directly to *produce* changes in organisms. If these changes can be inherited, this will be a most important means of guiding evolution. It is not certain, however, that these direct effects of the environment on the body of an organism can be transmitted.

Whether this is true or not, there is another effect of the environment which has certainly had a great influence on the course of evolution. The principle was discovered by Darwin and by him called "natural selection." It refers to the fact that the struggle for existence among organisms is so severe that some will inevitably be eliminated. We have seen that this is true among all species. A hundred are born of two parents: only two of these, on an average, will be preserved. Which will be successful? In the long run, those will be preserved which are best adjusted to the conditions of the life which they meet. This fact is independent of how they came to be adjusted. This is known as the "survival of the fittest." "Fittest" merely means those best adapted to live and reproduce in the environment encountered. This process of natural selection does not cause variations, but it may make use of any

variation that arises, no matter what its source. Furthermore, it may use variations of small amount, or the more striking variations known as mutations. In so far as it acts, its result is to guide evolution into suitable adaptation to the conditions that are able in any degree to influence life.

393. **Evolution and Man.**—Many people are deterred from accepting the general theory of evolution because of unwillingness to believe that man and his high mental and moral qualities could have come about in this fashion. It is of course impossible absolutely to prove that man or any other animals have thus evolved from the lower orders. All that can ever be done is to make it the most reasonable explanation. In reality it cannot make any material difference, one way or the other, whether man developed or was created outright. Just as much divinity is necessary in the evolution of man as in outright creation, and no quality of man is any less valuable or dignified under the assumption that it has grown than under the assumption that it was made outright. Man's moral place in the universe, like his place in American society, is properly determined by what he really *is* and not by the mere incident of the method of becoming.

394. **Topics for Themes in Zoology and English.**—I. Find definitions of evolution. Write one of your own.

2. What are some of the arguments that have been offered to support the view that "acquired" bodily characters are transmissible?

3. State some arguments that have been advanced against the view?

4. State briefly Mendel's laws of heredity. Illustrate.

5. What does the *gradual* development of the physical, mental, and moral nature of the human individual suggest?

6. State DeVries' doctrine of "mutation" in a brief way.

CHAPTER XXX.

ECONOMIC ZOOLOGY.

395. Reference has already been made in the appropriate places in the text to some of the most important ways in which the various branches of animals are related to human welfare. We are now in a position to look back over the economic bearings of animals and to get a broader view of the part they play in the life of man. This is a point at which Zoology touches the interest of every citizen of the world, whether he has any other interest in it or not. This should be one of the chief features of the study of Zoology in our schools.

396. **An Analysis of the Ways in which Animals Affect the Welfare of Man.**—1. Helpfully: (a) as food; (b) for clothing; (c) in the saving of labor; (d) in scientific experiment and medicine; (e) for pleasure, as companions and pets; (f) in minor miscellaneous ways.

2. Hurtfully: (a) directly* hurtful or dangerous; (b) as causes or conveyors of disease in man; (c) as enemies of our friends among the animals; (d) as destructive to vegetation; (e) as injurious to various manufactured products.

These headings are by no means exhaustive nor of equal merit, but they will give the student some conception of the closeness of the bond between man and the rest of the animal kingdom.

397. **Animals as a Food Supply.**—The difficulties of human life have been such at various places and times that man has experimented with almost all kinds of food

that have held out any sort of promise of pleasure or nutrition. Notwithstanding this, very few of the invertebrates have been given a wide place in his bill-of-fare. The lowest forms eaten are the "trepangs" (holothurians) which are used in great numbers by the Chinese. In the branch of mollusks the oyster is at the head in importance. There are also a number of marine and fresh-water clams and mussels which are used in smaller numbers. Some species of gasteropods (snails) are prized in certain parts of the world. It is believed that the mussels were an important article of food to some tribes of North American Indians, and to some of the peoples of the old world when they were in a corresponding stage of development. Among the arthropods the lobster comes first in importance, although it has been fished to such an extent that the output is rapidly diminishing and the size of specimens is steadily decreasing. Crayfish, shrimps, prawns, and crabs are also used to some extent. The great class of insects furnishes only the honey of the honeybee.

Every class of vertebrates furnishes food species. The amphibians and the reptiles stand lowest in this respect. The frogs and turtles are their only edible representatives. The fishes, the birds, and the mammals furnish the staple meat foods. A very large per cent. of the fishes are recognized as edible. Many species of the sharks, even, are prized although they are actively carnivorous, and the carnivorous animals have usually not been regarded as good to eat. Many species of birds have been eaten, but those that rank as of real importance belong chiefly to the Gallinæ, the Columbæ, and the Anseres. These three orders of birds supply to man hundreds of millions of dollars worth of his choicest food annually.

Among the mammals many species have been eaten, but the great division of ruminants and the swine furnish the bulk of the meat food now used by the human race. The horse is increasing in importance in this respect. Among uncivilized people, before the domestication and improvement of the ox, the sheep, and the hog, this division (ruminants) still furnished the chief wild game animals. Beside meat they furnish milk, butter, and cheese. In the far north the walrus, the bear, and the reindeer take the place of these well-known forms.

398. **Animals as a Source of Clothing for Man.**—In the case of primitive man the skins and furs of animals were the sole source of clothing and one of the means of making tents and dwelling places comfortable as well. As the art of weaving was developed and the discovery and perfecting of textiles derived from plants made headway, we became less dependent on the animals. But even now, in one form or another, the skins and the fur, hair, and wool of animals are among our choicest clothing materials. The mammals are of course the main animal source of clothing, but the warmth of feathers has long been recognized, and the skins and feathers of birds are used as articles of clothing by savage men and civilized women. The important mammals supplying the kind of hair suitable for clothing and for carpets and other coarser fabrics are: the various species of sheep and goats, the camels, the alpacas, and their relatives. Our leathers are made from the skins of these and related animals, and from some of the carnivora. Practically all the ruminants produce valuable leathers. Horse hides are also used for this purpose. The skins of many of the soft, thick-haired animals are dressed with the hair on, and

are known as furs. Most of these, as the seals, the sable, mink, ermine, weasel, raccoon, foxes, skunk, members of the cat family, and some others, belong to the carnivora. A few, as the squirrel, the hare, and the beavers (now almost extinct) are from the rodents.

One of the most marvelously delicate and beautiful of our fabrics, silk, is a secretion spun out by the larvæ of the silk-moth in making the cocoon in which it pupates, or changes to the adult stage. It is killed by being put into hot water, and then the silk thread is unwound. The silk industry is of much importance in China, Japan, Italy, and France.

399. Animals Used in Saving Human Labor.—In the earlier stages of civilization this help consisted of aid in hunting and capture of food-animals. The dog was probably one of the first animals domesticated. Later others came to be used for riding, for drawing loads in vehicles or otherwise, for plowing the soil, and the like. The camel, the ox, the horse, and the elephant rank among the most valuable in this respect. In the earlier civilizations of the orient, the camel has been of the utmost value. His adjustment to the tropical and semi-arid conditions is striking. The "ship of the desert" is an older means of commerce than the navigation of the sea. His relatives in South America, the llamas, have long been used as the chief animal of burden in the Andes. The reindeer is at once camel, horse, and ox of the frigid zone. The dog is also a beast of burden over the snows.

In modern times the horse has come to be one of the most valuable of animals used by man, ranking in money value next to the cattle in the United States. The mule,

which is a hybrid between the female horse and the male ass is a hardy, strong, infertile animal and one of our most valuable beasts of burden in agricultural communities.

Steam and electricity are replacing animal power at many points, but there is little likelihood that it will entirely displace them until population becomes so numerous that the animals are more valuable as food than they can be as labor-saving devices.

400. **Animals in Science and Medicine.**—A most interesting way in which animals have been of value to the human race grows out of the fact of the general likeness between man and the lower animals. It is safe to say that the great advances in surgery which have accomplished so much in the saving of human life have been made by early experimentation on animals in the laboratory, quite as much as by the actual direct study of the human body and its conditions. Experiments quite impossible of being made on human beings have first been tried on animals and have been found to accomplish what was expected of them. But it is not merely in surgery that they have shown themselves most valuable to human life. In all the work on antitoxins and serums with which to combat the germ diseases, the work must first be done on animals. The antitoxin of diphtheria comes from the horse; the virus by which we vaccinate for small-pox is obtained by giving the disease to the ox, which is only mildly affected by it; and so on through a considerable list of such diseases. The most hopeful work that is now being done to give us control of the terrible disease of cancer is being done on mice and rats, otherwise an enemy to human interests.

It has been discovered of late years that many organs of the body secrete into the blood that passes through them, or elsewhere, certain substances that have a most important bearing on life. Sometimes these organs become diseased and refuse to do their work. This may be true of the digestive glands, of the thyroid glands in the neck, and others. In such cases the gastric juice of the pig, or the thyroïdin obtained from the thyroid of the sheep, or pancreatin obtained from other animals may be administered in such a way as to carry on the function or even to overcome the disease.

Frogs, rabbits, guinea-pigs, cats, dogs, sheep, cows, horses, and monkeys are among the animals that have been most useful in these respects.

401. **Miscellaneous Uses of Animals.**—A long list of minor and exceptional uses of animals could be mentioned. The dog and cats have some protective value about the homes of men, where they were long before recorded history began. They have kept homes free of vermin, as rats and mice and the smaller animals, and the dog has doubtless been of protection from other enemies. They have been companions for childhood through all history.

The skins and tendons and bone of animals figured largely in all the early home industries, as sewing and tying and the like. In modern times the skins are used in many ways, as rugs and home ornaments, in the making of bags and other receptacles. Horn, bone, and ivory from the teeth and tusks of animals are largely used in knife handles, piano keys, billiard balls, and numerous other objects. Whale oil (sperm oil) has long been used in making candles, though it has been supplanted by the

cheaper mineral oils. Bristles, brushes, perfumes, oils, glue, buttons, and fertilizers are only a portion of the numerous by-products of the modern meat-packing houses. Ornaments are made of teeth, of corals, and of pearls. Many animals are scavengers, attacking and destroying carrion and other decaying organic matter.

402. Animals Directly Injurious to Man.—When man first appeared on the earth many mammals now extinct, much larger and fiercer than those of the present time, were abundant. Unquestionably these were much more of a menace to him than the predaceous animals are now. These animals, except in a few poorly inhabited parts of the world, are now practically negligible. A few poisonous snakes, some sharks and crocodiles, a few members of the cat family, and a few species of bear, almost extinct, about exhaust the list of animals really dangerous because of size or ferocity. But in place of these there are now numerous species that are no less dangerous to him because of diseases which they bring to man directly or indirectly. Reference has been made to the Protozoa which produce malaria and yellow fever, and to the intestinal and other parasites that belong to the unsegmented worms and produce all sorts of discomfort, inefficiency, and disease among men. The mosquitos and flies and other insects that spread these diseases are just as important to us as the germs themselves. The bubonic plague is believed to be a disease of rats and other rodents carried to man from the rat by fleas. All these temporary external parasites that go from animal to animal, as lice, fleas, bed-bugs, mosquitoes, etc., are especially favorably situated to be the carrier of disease. Cattle are subject to tuberculosis; and many investigators

believe that this is the same as the human disease, or at least that it is intercommunicable in man and cattle.

403. Animals Hurtful to our Animal Friends.—Our domestic animals are apparently almost as open to diseases as man himself. Hence it is that there are many animal diseases, caused by the various parasites of blood and organs. The Texas fever of cattle; the hæmoglobinuria of cattle and sheep; pébrine, a disease of the silk-worm; the sleeping sickness of Africa; etc., are due to protozoa, and are carried by ticks, flies, and the like. The liver-rot and staggers of sheep, and the various tape-worm and hook-worm diseases of hogs, dogs, cattle, and man are caused by the unsegmented worms. The “bot” diseases of horses, sheep, and cattle are produced by the larval stages of flies. Mange, itch, etc., as found in various domestic animals, is due to the action of mites.

404. Animals Hurtful to Plants and Plant Products.—At this point animals, more particularly the insects, do great damage to man's interests. The story is too long to tell here, but insects attack plants at every stage of their history from the time they germinate until the time they are stored. They devour foliage, fruits, timbers, seeds, stored grain, and manufactured products. It is said that “the elm has eighty species of insects that are more or less supported by it; birches and maples, over one hundred; corn is attacked by about two hundred species, of which fifty do notable injury and some twenty are pests; apple insects number some four hundred species.”

It is estimated that the farmers and fruit growers of America alone lose 500,000,000 dollars annually from the ravages of insects on crops and forests. Man has done much to control most animals except the insects,

and something to control them. The most effective means thus far found is by spraying plants, to keep away the females when about to lay, or to kill the young; the rotation of the crops in such a way that the insects may hatch without finding the kind of food on which they depend; and the introduction of animals, either predatory or parasitic, that attack the hurtful species.

Occasionally through a period of years such animals will multiply to such an extent as to become a plague, when in ordinary years they merely reduce the returns of the agriculturalist. Such are the outbreaks of the Rocky Mountain locust, the Hessian fly, the San José scale, the chinch bug, and the like. Less frequently similar things happen in respect to other animals, as the plague of rabbits in Australia, and of the rats in the Bermudas.

405. Domestication of Animals.—Occasional reference has been made in the preceding paragraphs to the *domestic* animals. This means something quite different from the merely useful animals. This term refers to the control by man of the life and habits of animals to such degree that he can work his will with them almost irrespective of the natural conditions. This domestication began before man emerged from the savage state—before recorded history began. The dog and cat were doubtless among the earliest forms, and the camel, the horse, the sheep, the donkey, the hog, the pigeon, the chicken, all have been very long in domestication.

The qualities that would make an animal suitable for domestication, and which doubtless helped to determine what forms should be domesticated, are: some gentleness of temper and lack of extreme nervousness, capability

of taking training, ability to become adapted to new surroundings, some love of locality, and usefulness for food or for some other of man's real or fancied needs. The effect of domestication on animals has been to soften and dull their original wild instincts, to render them less active and alert, to render them dependent on the care which man gives them, and to produce a tendency to take on fat easily when food is plenty.

406. **The Animal Industries.**—The animal industries cluster chiefly, but not wholly, about the domestic animals. These domestic industries relate to horses, cattle, mules, sheep, hogs, poultry (including chickens, turkeys, pigeons, geese, and ducks), and constitute a large part of agriculture in the United States to-day. The successful pursuit of these industries involves a scientific knowledge of the animals reared and of their possibilities and demands. Much of this in the past has been done in a haphazard sort of way, somewhat incidental to the raising of crops. In the last half-century, however, there has been a better application of the known principles of stock-breeding and of selection than before. The modern stock-breeder crosses and re-crosses various strains of cattle or hogs in order to get variety of result. Then he selects what pleases him most and breeds that in such a way as to fix and increase the features which he regards as most profitable, whether it be swiftness, size, milk-giving, cream-producing, finer wool, fertility, or the power to take on fat. This is the reason we have so many varieties of all the animals that have been long in domestication. Different breeders have been, more or less consciously, selecting different qualities in animals. Men are now pushing this process even further, and are

purposely and systematically producing and selecting new and better breeds. The evolution will be correspondingly more rapid.

All the animal culture mentioned above is done in connection with plant culture and often on the best land the country has. There are other industries which have great possibilities in regions not suited to agriculture. Man has used some of the natural resources of these less used regions in a very prodigal and reckless way. He has not taken pains to look ahead and to act scientifically, simply because he has not been compelled to do so. The time, however, has come when the farmer uses systematically the less productive parts of his farm as well as the more fertile. If not fit for cultivation he uses it for sheep or goats or something which is best adapted to it. So it must be in the future with the whole earth. The oceans, the rivers, the swamps, the ponds and lakes, the arid regions, and the mountains must be stocked with animals that will contribute to man's food. These animals must be helped to take the place of those which are of no use. This means that the various fishing industries, as mackerel, cod, herring; and even more particularly the fresh-water fisheries, as the salmon, whitefish, and other lake and river fish, shall be more than the mere catching and canning of such fish as have been able to fight their own way through to successful maturity; they will include the bending of all possible agencies to the building up, improving, and maintaining the numbers and quality of these fish. Oyster, lobster, pearl-mussel, and sponge fishing will be more than merely to put on the market the biggest possible amount regardless of the future; it will rather be the stocking of all suitable places of the ocean margin that are not more profitably

used for something else with the young of the types wanted, keeping away the enemies of the species as well as possible, and doing artificially all that can be done to insure their steady and profitable growth. The scientific treatment of these industries means the putting on the market only those that have got their best growth and with the least injury to the partly grown individuals, just as it does on the farm or in the forest.

The conservation of our natural resources also means that the swamp lands, that cannot be drained and used more profitably, and the shallow streams shall be made to produce edible frogs or turtles instead of the other inedible amphibians and reptiles. Wherever edible fish can grow pains will be taken to place them and see that the conditions of their best life are given them.

Various bureaus of the United States Government, as that of Animal Industry, of Fish and Fisheries, of Entomology, and the like; the Agricultural Experiment Stations of the various States; the scientific men in the universities and colleges, and many practical workers who are in these fields in a commercial way are studying the problems suggested in this chapter and are trying to add to the vital resources of the human race and its increasing population. It is the duty of every American to get into a sympathetic attitude to all this work.

407. Topics for Themes in Zoology and English.—1. Give a report of the United States Bureau of Fish and Fisheries. How is it organized? What are its principal stations? What work does it undertake to do? What are its chief publications?

2. Discuss similarly the Bureau of Animal Industry; the Bureau of Entomology; the Biological Survey.

3. Give an account of one of the inland fish hatcheries and its work.

4. Why are the vegetable feeding animals preferred for food above the carnivora?

5. Why are woolen fabrics warmer than cotton or linen?
6. Will the vegetable food or the animal food that can be produced and supported on ten acres of ground go further in supporting human life? Discuss carefully.
7. Do you think the tendency will be to increase or to decrease animal culture as population begins to press upon the resources of the soil? Give the biological reasons fully.
8. What are the chief arguments against vivisection and experiments on living animals by investigators? What the chief arguments in favor of it?
9. Discuss the various products of the hog utilized in the packing houses.
10. Discuss the animals that frequent human habitations, becoming pests in some degree. Give the habits of life of each so far as you can by study and reference.
11. Discuss with some care what is known of the history, the different varieties, the uses, etc., of some of the domestic animals, as the dog, the horse, the fowl, the ox, and others.
12. Discuss human slavery as a Zoological phenomenon. To what is due the tendency to abolish it?

APPENDIX.

I. *Sources for Materials*.—The great majority of the animals studied should be those native to the locality of the class. Sometimes, however, it is necessary to supplement the native supply at seasons when it is not readily to be had, or to secure types not well represented there. The following are a few of the reliable dealers in biological material. Most of them publish price lists.

Supply Department, Marine Biological Laboratory, Wood's Hole, Mass. (Preserved materials.)

Henry M. Stephens, Carlisle, Pa. (Preserved and living animals.)

Dr. F. D. Lambert, Tufts College, Mass.

Aquarium Supply Co., Delair, N. J. (Living animals).

A. A. Sphung, North Judson, Indiana. (Living frogs, turtles, clams, crayfish.)

The writer's laboratory (Millikin University, Decatur, Ill.) will be able to furnish a limited number of microscopic slides to illustrate cell structure, cell division, tissues, cleavage, gastrulation, sections showing the typical arrangement of organs in sponges, coelenterates, worms, amphioxus, etc. These are often valuable for demonstration or to stimulate extra study.

The University of Kansas (Lawrence) will supply specimens at cost to the secondary schools of the State. Other State universities are glad to help teachers wherever possible.

II. *Some Valuable Books for the Reference Library.*—Only a few titles are recorded here. Other books will be suggested in appendices of these books.

1. Thompson, J. A. *Outlines of Zoology.* D. Appleton & Co., New York. \$4.00.

2. Parker and Haswell. *Text-book of Zoology.* 2 Vols. The Macmillan Co., New York. \$9.00.

3. Jordan, D. S. *Animals.* D. Appleton & Co. \$1.80.

4. Verworn, M. *General Physiology.* Macmillan Co. \$4.00.

5. LeConte, J. *Outlines of Comparative Physiology and Morphology of Animals.* D. Appleton & Co. \$1.80.

6. Thompson, J. A. *Heredity.* J. McMurray, London.

7. Galloway, T. W. *Text-book of Zoology.* P. Blakiston's Son & Co., Philadelphia. \$2.00.

8. Poulton, E. B. *Colors of Animals.* D. Appleton & Co. \$1.25.

9. Darwin, Charles. *Animals and Plants Under Domestication.* D. Appleton & Co. \$5.00.

10. DeVries, Hugo. *Species and Variation.* Open Court Pub. Co., Chicago.

11. Hodge, C. F. *Nature Study and Life.* Ginn & Co., Boston.

12. Morgan, C. L. *Habit and Instinct.* Edward Arnold, New York. \$4.00.

13. Folsom, J. W. *Text-book of Entomology.* P. Blakiston's Son & Co. Philadelphia. \$3.00.

14. Comstock, J. H. *Manual for the Study of Insects.* Comstock Pub. Co., Ithaca, N. Y. \$3.75.

15. Kellogg, V. L. *American Insects.* Henry Holt & Co., New York.

16. Emerton, J. H. *Common Spiders.* Ginn & Co. \$1.50.

17. Howard, L. O. Mosquitoes. McClure, Phillips & Co., New York. \$1.50.

18. Chapman, F. M. Bird Life. D. Appleton & Co. \$2.00.

19. Chapman, F. M. Handbook of Birds of Eastern United States. D. Appleton & Co. \$3.00.

20. For the emphasis on the economic side of Zoology the teacher should secure *all* obtainable publications of the following: U. S. Department of Agriculture, such as the Year-book, the Farmers' Bulletins, the Bulletins of the Department of Animal Industry and of the Division of Entomology; the Reports and Bulletins of the U. S. Fish Commission; the publications of the various State Biological Surveys; the reports of the State Entomologists; Bulletins of the State Experiment Stations and of the Agricultural Colleges. This is the most important printed matter that can be had for this part of the work and can often be had for the asking, or at most for a very nominal sum. Write your Representative in Congress and your State university for a start in this, and ask for a list of the printed matter open for general distribution or purchase. It is often well to get several copies of some of these publications in order that the students may make the freest use of them.

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