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PRINCIPLES

OF

ECONOMIC ZOÖLOGY

PART I

Field and Laboratory Guide

BY

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PREFACE

A SATISFACTORY course in Zoölogy requires field, laboratory, and text-book work on a series of typical animals. This method will bring the student into contact with the animal world in its manifold relations.

The teacher may follow any order which he prefers, but the studies in this guide are arranged with a view to seasonal supply. Insects are plentiful and easily obtained by the class in the fall, while fishes, frogs, and turtles may be kept in aquaria or purchased at any time from dealers in zoölogic supplies. Also, the dissection of the vertebrate forms is less unpleasant in the winter. Earthworms and lower forms may be obtained in the spring.

Zoölogy is a study of animals and not information about animals. As Ruskin says, "the greatest thing in the world is for a man to see something and to tell clearly what he saw." It is intended that the student find his answers in the animal before him.

Things he cannot get from the animal in the laboratory he should get from the study of the animal in the field, or, where this is impossible, from descriptive zoölogies. "Principles of Economic Zoölogy," Part II, is intended to supply this need.

In the preparation of these studies, helpful suggestions have been used from time to time from various authors, but they are largely the result of many years' teaching of Zoölogy, of personal investigation, of travel and observation from the Atlantic to the Pacific, and in the best schools of Europe.

THE AUTHORS.

KIRKSVILLE, MO., *November*, 1912.

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PRINCIPLES OF
ECONOMIC ZOÖLOGY

PART I

FIELD AND LABORATORY GUIDE

TO THE TEACHER

The purpose of these studies is not to obtain a few facts about the structure and life-history of animals, but to lead the student to discover the principles which underlie these facts and to bring him to see that the same fundamental principles apply to all animal life, including man.

The teacher is entreated not to fail to use the General Studies as indicated, especially upon the forms from Arthropoda up, and not to be worried because of the repetition of the same questions for different animals. Study to see how these questions may or may not be applied, and why. Remember, we are after principles. The study of the live animal, both in the field and laboratory, will be found to give a new and vital interest to the subject. If you will persevere in the use of these studies *as they have been planned*, Zoölogy will grow to have a fascination for you and your students which mere facts, however abundant and accurate, can never give.

It is not expected that all of these animals will be studied every year. Each teacher must determine the kind and amount of work he can undertake with his classes. He must find out what he can best use and what he can most easily obtain. One year some material may not be obtainable, and another year, easily obtainable; or lack of time or opportunity may necessitate the omission of a certain suggested study. However, these changes will make the work new each year, and students cannot copy from the note-books of the previous year.

TO THE STUDENT

THE study of animals is a fascinating subject, but, remember, you *must study the animals.* A machine is interesting to you if you can experiment with it, just to see what you can do with it or make it do for you. Just so with animals, you must study the animal "machine," living and dead, to understand something of what it can do and the why of its existence. Everything about a machine is there for some purpose. So in an animal, everything you see has or has had a use. You may not be able to determine what it is, but you can try to find out in the same spirit you try to find out the use of the parts of a machine. In your study of the animal machine you must use your mind and some tools to enable you to find out the wonderful make-up of it, for it is far more wonderful than any other machine you ever worked with.

The dissection may not be pleasant to some of you, but all things worth while cost something. Forget the odors and "ask the animal" what you want to know. Look and think of what you are trying to find and of its use to the animal. Look even further, for the principles which underlie its structure and use. Finally, you will see that you have much in common with the animals about you. You are influenced by your environment and heredity much as they are. You will see also that you are dependent upon them for many things necessary to your daily existence and comfort. Get your eyes open while you are alive. See and enjoy the beautiful, wonderful world in which you live.

THE LABORATORY

The equipment for good work will depend very largely on the energy, initiative ability, enthusiasm, and tact of the teacher. A live animal, a live pupil, and a live teacher would constitute a live and interesting class with no other equipment, while, without these, an expensive equipment will arouse little or no interest. The following equipment will be found very helpful:

(1) Magnifying glasses of ten and twenty magnification power are found to be the most satisfactory for class use.

(2) Compound microscopes. One for two students gives good results, but one for each student is the ideal plan.

(3) Dissecting instruments. These may be purchased for $1 per set and kept in stock for class use, or each student may use his own set.

(4) Tables with lockers in which students may leave their notes and instruments from day to day are essential.

(5) Insect net. (See under Insects, p. 56.)

(6) Cyanid bottle. (See p. 54.)

(7) Material: (a) Marine material may be purchased of the Marine Biological Laboratory, Wood's Holl, Massachusetts.

(b) Inland forms may be obtained from Alfred W. Jones, Salina, Kansas, or from N. O. Lawson, Geneva, Illinois.

(c) Local material should be collected by the teacher and class as field exercises. It may also be purchased inexpensively from small boys, who are ever ready to earn a few pennies.

(d) Stock material may be kept in from 2 to 5 per cent. formaldehyd or formalin.

Fish, frogs, and such forms should have a few cuts in the body to admit the preserving fluid to the internal organs.

Take 1 part, by measure, of formalin and 19 parts, by measure, of water for preserving insects for class use.

For temporary use, small vertebrate forms may be kept in a strong solution of common salt. This draws out the blood and, if poured out and renewed occasionally, gives excellent satisfaction.

For class use it is an excellent plan to have each student keep his specimen in a glass fruit-jar, labeled with his own name.

Reading List.—The teacher should make a list of available books on animals for the students' use. Give the author and page of the book where the desired information is to be found. This reading list is very helpful for points which are hard to get from the animal.

"The Teaching of Biology," by Lloyd and Bigelow (Longmans, Green and Co., N. Y., $1.50), is very helpful to the teacher. It contains scores of references to biologic subjects.

PLAN FOR USING LABORATORY STUDIES OF TYPIC ANIMALS

The authors have found by experience that the following order of studies is a good plan for each type:
Study of the Live Animal.

I. General Preliminary Study. The student should learn to take such points as he can answer from the animal, omitting only such as do not apply to the animal under consideration. "Ask the animal, do not ask the teacher."

II. Ecologic or Environment Study. All points which apply to the animal under consideration, numbering your answers accordingly.

III. Study of Animal Behavior.

IV. Special Morphophysiologic Study.

V. Systematic Study of the branch, class, and order to which the animal belongs.

VI. Final Study, which should be preceded by the study of the descriptive text.

These studies give the student a formula to follow in studying animals from different viewpoints, and fix the facts and principles in his mind.

Each teacher will observe that the Studies I, II, and III do not require dissection, but are intended to give the student a preliminary view of the live animal, if possible, but in any case, with the animal before the student. Then follows the Morphophysiologic Study, or the dissection, for which a separate study is provided for each animal type.

LABORATORY STUDIES UPON TYPIC ANIMALS[1]

I. GENERAL PRELIMINARY STUDY

1. General characteristics of this animal as to—
   (1) Head,
   (2) Body,
   (3) Appendages,
   (4) Mouth,
   (5) Ears,
   (6) Eyes, or as many of these as you can identify and describe briefly.

2. Symmetry. Is this animal asymmetric, radial, or bilateral?

3. Habitat. Is this animal aërial, aquatic, terrestrial, or subterranean?

4. Food.
   (1) Is this animal carnivorous, herbivorous, or omnivorous?
   (2) How does it obtain its food?
   (3) Is there anything about the *structure* of this animal to suggest how it gets its food? To suggest the character of its food?

5. Locomotion.
   (1) How many appendages or limbs has this animal?
   (2) Is it fixed or free? What effect does this have upon its development and movements?
   (3) Is its locomotion affected by body movement, by limb movement, or by both?
   (4) Upon what part of the body, limb, or foot does it move from place to place?
   (5) What is its locomotion called?
   (6) Rate of locomotion as compared with that of man?

6. Self defense.
   (1) Name its direct means of defense.
   (2) Name its indirect means.

[1] See Plan for using these studies, p. 5.

7. Rivalry.
   (1) By battle? If so, how?
   (2) By song?
   (3) By color or by what means? Describe accurately.
   (4) Adaptations for rivalry. Spurs, horns, quills, bill, fine feathers, or what means?
8. Covering.
   (1) Consists of scales, fur, shell, or what?
   (2) Variations of the covering on various parts of the body or appendages?
9. Color.
   (1) General color of this animal?
   (2) Color of its head?
   (3) Color of its tail?
   (4) Color dorsally?
   (5) Color ventrally?
   (6) Color laterally?
   (7) Color of limbs or appendages?
   (8) Describe color patterns accurately.
10. Resemblances.
   (1) Any protective resemblance? If so, what?
   (2) Why?
   (3) Does the attitude of this animal affect this resemblance? If so, how?
11. Parasites.
   (1) Is this specimen a parasite? If so, upon what?
   (2) Effect of this parasitism upon the parasite?
   (3) Effect upon the host?
   (4) Is this animal a host for a parasite? If so, for what?
   (5) Effect upon the host?

12. Sketch. Make a sketch of this animal and name the external parts. If the animal is small, make the sketch life size or larger.

II. ECOLOGIC OR ENVIRONMENT STUDY

Environment is considered as everything outside the animal which may affect it.

1. Is the environment of this animal—
   (1) Aquatic,
   (2) Terrestrial,
   (3) Subterranean,
   (4) Arboreal,
   (5) Aërial, or
   (6) Some combination of these?

2. Change its environment from.....to.....
How would this change affect its—
   (1) Structure,
   (2) Food,
   (3) Enemies,
   (4) Dispersal,
   (5) Barriers,
   (6) Locomotion, and
   (7) Covering?

3. Organic Forces (animals and plants).
   (1) What influence upon this animal has a scanty vegetation? An abundant vegetation?
   (2) What influences have animals of the same kind? Of different kinds?

4. Aqueous Forces. Influence upon this animal of rain, snow, sleet, hail, or ice?

5. Atmospheric Forces. Influences of the *direction* and *velocity* of winds?

6. Igneous Forces. Influences of the varying temperature from day to day and from month to month? During what months is this animal most active? Least active?

7. Weather. Influence of such weather as to-day on this animal?

8. Climate. Influence of this temperate climate on this animal?

9. Make a list—
   (1) Of all the environment factors that favor this animal.
   (2) Of those that are unfavorable to it.

10. State briefly your estimate of the influence of environment, past and present, on this animal.

III. ANIMAL BEHAVIOR

Teacher, designate such of the following as you wish to consider for the animal you are studying. Student, do not guess your answers. Find out by observation, experiment on the animal, and by reading in advanced zoölogies.

1. Irritability. How shown? Why shown? Use?
2. Reflexes.
   (1) Automatic actions. Name those of this animal? Why automatic?
   (2) Reflex actions. How, when, and why shown by this animal? Are these conscious or unconscious?
3. Sensation.
   (1) Sense of touch.
      (a) Strong or weak? Why?
      (b) Relied upon for what information by this animal?
   (2) Taste.
      (a) Evidences of this sense?
      (b) Well or poorly developed? Why?
      (c) Relied upon for what information?
      (d) Organs of taste? Their location?
   (3) Smell.
      (a) Is this sense of smell well or poorly developed? Why?
      (b) Evidences of the sense of smell?
      (c) Relied upon for what? Used at long or close range?
      (d) Any motion of the organs?
   (4) Sight.
      (a) Describe the organs of sight. Their location.
      (b) Relied upon for what?
      (c) Used at long or close range?
      (d) What portion of a circle, of which this animal is the center, can it see without turning its head? Without turning its body? How?
   (5) Hearing.
      (a) Location of organs?
      (b) Are they well or poorly developed?
      (c) Consist of what?
      (d) Relied upon for what?

(e) Used at long or close range?
(f) Their motions, if any? Purpose of these motions?

4. Instincts.
(1) Egoistic Instincts.
(a) Feeding.
(1) What particular food-securing instincts has this animal? How shown?
(2) Adaptation for securing food?
(b) Self-preservation.
(1) What instincts of self-preservation has this animal? Defense, concealment, flight, feigning death, or what?
(2) What are its adaptations for self-preservation?
(c) Environment Instincts.
(1) Climatic instincts. Name them.
(2) Atmospheric, those induced by the weather. Name, if any.
(3) Aquatic. If the animal lives in the water, substitute number (3) for number (2), and name the instincts induced by the water in which the animal lives.
(d) Instinct of sleep.
(1) When shown?
(2) Purpose?
(e) Play. Has this animal any instinct of play? If so, what?
(1) Is it social or solitary?
(2) Purpose of play to this animal?
(f) Strife.
(1) When shown?
(2) Why shown?
(g) Hunting.
(1) Adaptations for?
(2) Purpose?
(2) Altruistic Instincts.
(a) Courtship. By male or female?
(b) Reproduction. Sexual, asexual, or both?
(c) Home making. By male or female?
(d) Care of young. How?

5. Emotions.
   (1) Which of the following emotions have you seen this animal show? Surprise, fear, parental affection, pugnacity, industry, curiosity, jealousy, anger, emulation, pride, love of ornament, grief, hate, cruelty, revenge, shame, deceit.
   (2) Which of the above-named emotions do you infer that it has? Why?
6. Voice or Sound (if any).
   (1) How, when, where, and why made?
   (2) Called what?
   (3) Made by the male, the female, or both?
   (4) Organ, or organs of voice?
   (5) Location of sound-making apparatus?
   (6) Range of voice or sound?
   (7) Make a list of the sounds made by this animal.
   (8) Significance of each sound made?
   (9) Can this animal communicate with its own kind? If so, how?
7. Memory.
   (1) State your proof for or against this animal's having memory.
   (2) Of its own young? Instances.
   (3) Of its own species? Instances.
   (4) Of different species? Instances.
   (5) Of direction? Instances, if any.
   (6) Of place? Instances.
   (7) Of past experiences? Instances.
   (8) Of man? Instances, if any.
8. Reason.
   (1) Does this animal learn from past experiences? Prove your position on this point.
   (2) Does it have the power of adaptive choice? Prove statement by examples observed.
   (3) Does it have the power of abstract thought?

9. Intelligence. Is this animal high, medium, or low in the scale of intelligence? Upon what do you base this statement?

IV. MORPHOPHYSIOLOGIC STUDY OF THIS ANIMAL

V. CLASSIFICATION OR SYSTEMATIC STUDY[1]

1. This animal belongs to Branch.....because it has these branch characteristics:.....(Student name them.)
2. To Class.....It has these class characteristics:.....
3. To Order.....It has these ordinal characteristics:...

Advanced Study—

4. To Family.....It has these family characteristics:....
5. To Genus.....It has these generic characteristics:...
6. To Species.....It has these specific characteristics:...
7. Scientific Name:.....
8. Common Name:.....

Remark.—The student will discover these characteristics from the animal and from consulting advanced works on zoölogy. Endeavor to get a correct idea of what scientists mean by branch, class, or ordinal characteristics. Get the Principles of Classification.

VI. FINAL ORAL OR WRITTEN STUDY

Note.—This study is intended to be taken *after* the examination and the dissection of the animal has been completed, and the test has been carefully studied upon the type considered. The answers, then, may be based upon the student's *own observations* or upon his study of the text and reference books. Some of the general headings have been repeated here, but nearly all of the questions under them are new, and such as were purposely omitted from the other studies in order that the animal might be gotten through with as quickly as possible, and thus all unpleasant odors avoided.

1. Skeleton.
   (1) Use of this skeleton to the animal?
   (2) Use of this skeleton to man?
2. Size. Do male and female differ in size? If so, how? Why?

[1] This study should be taken after the Morphophysiologic Study of This Animal.

3. Struggle for existence. Give reasons for the threefold struggle for existence among animals.

4. Digestion. What advancement or degeneration is there in the organs of digestion of this animal compared with those of the last animal studied?

5. Circulation. What advancement or degeneration in the circulatory organs as compared with those of the last animal studied?

6. Respiration. What advancement or degeneration, if any, in the organs of respiration of this animal as compared with those of the last animal studied?

Any difference in the respiratory organs of the young from those of the adult animal?

7. Nervous System. What advancement or degeneration in the nervous system of this animal, as compared with that of the last animal studied?

8. What organ, if any, appears here for the first time in the animal kingdom?

9. Any metamorphosis? If so, name the animal in each stage of its development.

10. Home.
   (1) Its home is called nest, den, or what?
   (2) Location of home?
   (3) Materials used?
   (4) Tools used in making the home? How is the home made?
   (5) Purpose of the home?

11. Food.
   (1) Food of the young?
   (2) Food of the adult?
   (3) Food in summer? Does it vary from that of winter? How?
   (4) How does this animal obtain its food?
   (5) Where does it obtain it?
   (6) When does it obtain it?
   (7) Does this animal injure man's crops? If so, how? Remedy?
   (8) Is it in any way beneficial to man's crops? How?

12. Enemies.
   (1) What is this animal's particular mode of defense against them?
   (2) Does it have any peculiar mode of attacking them? If so, what?
   (3) Name its means of defense.
   (4) What are the enemies of the young?
   (5) Does the male or the female defend the young?
   (6) Is the young able to defend itself? If so, how?
13. Covering.
   (1) Does the covering of the young differ from that of the adult? If so, how? Does it ever change in thickness from environment causes?
   (2) Uses of this covering to the animal?
   (3) Use to man?
   (4) What inferences as to the habits and habitat of this animal do you draw from its covering?
   (5) Does this animal have an ecdysis? Describe.
14. Color.
   (1) What gives this animal its color?
   (2) Significance of its color and color patterns?
   (3) Does the color of the young differ from that of the adult? If so, how? Why?
   (4) Does the color of the male differ from that of the female? If so, how? Why? When?
   (5) Does the color of different individuals of the same sex vary? If so, how? Why?
   (6) Does the color of the same individual vary at different seasons or under different environment conditions? If so, how? Why?
15. Resemblances.
   (1) Any special protective resemblance? (S. P. R.)
      (a) If so, what does it resemble?
      (b) How?
      (c) Why?
   (2) Any variable protective resemblance? (V. P. R.) Describe. Cause?
   (3) Any aggressive resemblance? (A. R.) If so, what does it resemble?

(a) How?
(b) Why?

(4) Mimicry.
(a) What does it mimic?
(b) Just how does it resemble the mimicked species and how does it differ from it?
(c) What advantage does it gain by this mimicry?
(d) Is this animal conscious of its mimicry? Is the mimicry voluntary?

(5) Attitude. Does this animal assume any particular attitude for protection? If so, how does this attitude affect its protective resemblance?

16. Warning Colors. If any, describe accurately the color and color patterns.
(1) Of what use are these colors to the animal?
(2) Of what do they warn the enemy?
(3) How do the habits of animals having warning colors differ from those of animals having protective resemblance?

17. Alluring Colors.
(1) If any, describe them minutely, and tell how they are used to allure, and why?
(2) What difference, if any, between the alluring colors of the male and those of the female?

18. Recognition of its Own or Different Species.
(1) By color. If the recognition is by color, state color, and accurately describe color patterns.
(2) By sound. If by sound, what is the sound called?
(3) By odor. If so, how and when is it used? Upon what part of the body is the odor secreted?
(4) By shape, by contact, or by what means?
(5) When, how, and why does this animal make use of its means of recognition?

19. Terrifying Appearance or Attitude. If any, how, when, and why shown?

20. Relations with Other Animals.
(1) Is this animal solitary, social, or gregarious? Why?
(2) What is a number of these animals together called—a herd, a swarm, or what?

(3) Any commensalism or symbiosis?
  (a) With what animal?
  (b) Effect upon each?
(4) Is this animal diurnal, crepuscular, or nocturnal in its activities? Why?

21. Multiplication.
(1) Is this animal hermaphroditic?
(2) Is it dimorphic, trimorphic, or polymorphic?
(3) Does it have alternation of generations?
(4) Is its multiplication sexual, asexual, or both?

22. The Young.
(1) Number in a brood?
(2) Number of broods in a year?
(3) Are the young precocial or altricial?
(4) Time required to reach growth or maturity?
(5) Average length of life of this species? What relation between the growing period and the length of life?

23. Activities Due to Environment.
(1) Does this animal migrate, hibernate, or remain active in winter?
(2) If it hibernates, how or in what does it hibernate?
(3) If it migrates, to what place or conditions does it go?
(4) Does it go singly, or with others of its kind?
(5) Does it migrate, estivate, or remain active in summer? If it migrates, to what place does it go? Why? When does it go? When return?

24. Geographic Distribution.[1] State as accurately as possible the geographic distribution of this family or species of animals.
(1) Do any of its habits or features of structure vary in different localities? How? Why? Examples.
(2) Name some of the means of dispersal of this animal.
(3) Name the barriers to dispersal. Why are these conditions barriers to the dispersal of this particular animal?

25. Geologic Distribution.[2]
(1) In what era did its Branch and Class appear?
(2) Are the individuals of this class more numerous than in former geologic eras?
(3) Are they more or less highly developed?

[1] See Daugherty's "Economic Zoölogy." [2] See a good geology.

CRUSTACEA[1]

STUDY OF LIVE CRAYFISH

1. Collecting.
   (1) Day Field Trip.
      (a) Look along the edges of shallow ponds and streams.
      (b) Look under stones in the shallow rapids of small streams.
      (c) What means have the crayfish of evading or escaping you?
      (d) Where do you find the crayfish holes most numerous?
         (1) Note their depth.
         (2) Do the holes all have chimneys?
         (3) Did you ever find the chimney stopped up with mud? What kind of weather was it?
         (4) Do the crayfish live singly or in pairs?
   (2) Evening Field Trip. Try again at night, by placing a bright light where it will shine down into the water. Crayfish will be attracted by the light and may be captured with the net,[2] which, for use in the water, should be of strong, open-meshed goods like seine cloth.
      (a) Do you find crayfish active in the daytime or at night?
      (b) Are they solitary or gregarious?
2. Aquarium.

The habits and activities of crayfish may be advantageously studied in a tank or any sort of an aquarium where the water may be changed occasionally.

   (1) Do they seek the light or the sheltered places?
   (2) Find out, by trying various kinds of food, whether they are herbivorous, carnivorous, or omnivorous.
   (3) Watch them feed and describe their feeding habits.
   (4) Find out all their kinds of locomotion.
   (5) What means of concealment have they?

[1] The study of Insecta may precede that of Crustacea in order to obtain live insects.

[2] See "Insect net."

(6) Means of defense—which do they do first, flee or fight?
(7) In flight, what kind of locomotion do they use? Just how is it performed?
  (a) Give two reasons why they go backward.
  (b) Molest one from behind. What does it do? Why?
(8) Try experiments to discover their range of sight.
  (a) What part of a circle can a crayfish see, since it cannot turn its head? How?
  (b) Can it see if there are any obstacles in its way when it darts backward?
(9) Find out if the surface of the body is sensitive to the touch.
(10) See if you can find any reason for two pairs of antennæ.
(11) Find out if the crayfish can hear, smell, or taste.
(12) Determine the direction of the gill-currents by placing a drop of ink near the anterior edge and one at the posterior edge of the carapace.

3. Development.

In early spring females with large, berry-like clusters of eggs, under the abdomen, will be found.

(1) To what are the eggs fastened? How?
(2) Take these female specimens to your aquarium and watch the eggs till they are hatched.
(3) The young.
  (a) Do they differ from the adults? If so, how?
  (b) Are they freed or attached to the mother? If attached, how?
  (c) Do they feed themselves, or are they fed by the mother at first?
  (d) What is their food?
(4) Molting.
  (a) Watch carefully for the process of molting.
  (b) How does the crayfish get out of its shell?
  (c) Did any accident happen to it while it was getting out? If so, what?
  (d) In what condition is the body when the shell is first removed?
  (e) Where does the newly molted crayfish stay?

I Take Preliminary Study.
II. Take Environment Study.
III. Take Animal Behavior.
IV. Take Morphophysiologic Study.
V. Take Systematic Studies for Branch and Class.
VI. Mount a crayfish.

MORPHOPHYSIOLOGIC STUDY OF THE CRAYFISH

A. External Morphology

I. General Observations.

1. Number of Segments. Zoölogists claim that the crayfish is composed of twenty segments. Begin with the last segment of the abdomen and see how many segments you can find. Each pair of appendages is attached to a different segment.

2. Length—from tip of rostrum (between the eyes) to the end of last segment.

3. Covering—the carapace. Its composition?

4. Cervical Groove—which shows where the head and thorax unite in the cephalothorax.

II. Body Divisions.

1. The Cephalothorax (head and thorax united).
   (1) Shape?
   (2) Length to abdomen?
   (3) Color?
   (4) The Eyes.
      (a) Number?
      (b) Kind (simple or compound)?
      (c) Sessile or stalked?
      (d) Location?
      (e) Motion?
      (f) Protection?
      (g) Color?
      (h) Use?
      (i) Sketch, much enlarged.
   (5) The Antennæ.
      (a) Number?
      (b) Shape?

(c) Location?
(d) Number of segments?
(e) Covering?
(f) Parts. (Take out one, sketch it, see Huxley or other large zoölogy, and name all the parts present.)
(g) Use?

(6) The Antennules. (a)–(g) as for antennæ.

(7) The Mandibles, or Jaws. A pair of hard toothed appendages.
(a) Shape?
(b) Location?
(c) Motion? Horizontal or vertical?
(d) Use?
(e) Mandibular palpi. Number to each mandible?
(f) Metastoma, a leaf-like structure posterior to each mandible.

(8) The Maxillæ—two pairs of thin appendages just posterior to the mandibles. With your forceps carefully remove them from one side. Be careful not to injure them.
(a) Shape?
(b) Use?
(c) Sketch each, much enlarged.

(9) The Maxillipeds—three pairs of similar appendages between the maxillæ and the large legs.
(a) With forceps carefully remove the maxillipeds from one side. Sketch each one, much enlarged.
(b) Use?

(10) The Legs. Five pairs.
(a) Remove the large leg on the right side and sketch it.
(b) How many segments has it?
(c) Sketch shapes into which you can arrange this "toggle-jointed" appendage.
(d) Use?
(e) Compare it with the second pair of legs, noting points of similarity and difference.
(f) Compare with the third pair.
(g) Compare with the fourth pair.
(h) Compare with the fifth pair.

2. The Abdomen.
   (1) Shape?
   (2) Number of segments?
   (3) Number of appendages (swimmerets)?
   (4) The telson, last segment, has no appendages.
   (5) The Swimmerets.
      (a) Remove and sketch the pair from the third abdominal segment. Note that it has a main stalk and two branches.
      (b) Compare it with the first pair, noting similarities and differences, or sketch both to show comparison.
      (c) Compare with second pair.
      (d) Compare with fourth pair.
      (e) Compare with fifth pair.
      (f) Compare with sixth pair.
      (g) Use of the swimmerets?
      (h) Compare with thoracic legs.
      (i) Compare with maxillipeds.
      (j) Compare with maxillæ.
      (k) Compare with mandibles.
      (l) Compare with antennæ.
      (m) Compare with antennules.
      (n) Compare with eyes.
      (o) Conclusion.—Appendages of the same essential plan or not?

B. Internal Morphology

Follow the same plan for dissection as in insect studies. Chloroform a fresh specimen or kill it by warm water, as directed for the clam.

1. The Circulatory System. Carefully remove, with scissors and forceps, the dorsal portion of the abdomen and about one-half inch of the carapace, and expose the heart, which is a whitish, oblong organ.
   (1) Pericardial cavity in which the heart is located. Use?
   (2) The heart.
      (a) Shape?
      (b) Size?

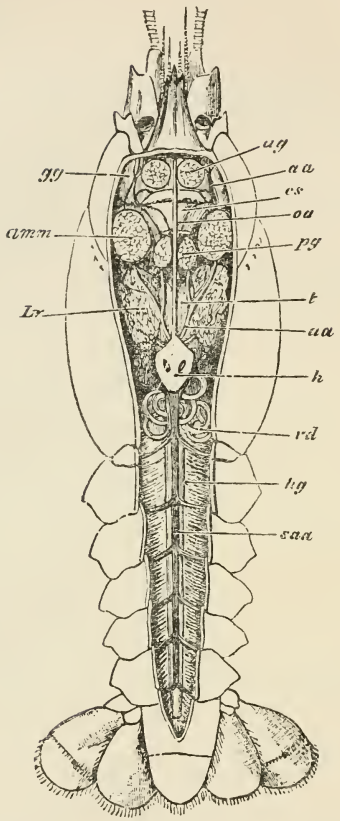

Fig. 1.—*Astacus fluviatilis*. A male specimen, with the roof of the carapace and the terga of the abdominal somites removed to show the viscera (natural size): *aa*, Antennary artery; *ag*, anterior gastric muscles; *amm*, adductor muscles of the mandibles; *cs*, cardiac portion of the stomach; *gg*, green glands; *h*, heart; *hg*, hind gut, or large intestine; *Lr*, liver; *oa*, ophthalmic artery; *pg*, posterior gastric muscles; *saa*, superior abdominal artery; *t*, testis; *vd*, vas deferens. (Huxley.)

(c) Openings—how many? Use?

(d) Trace small white tubes, arteries, to different parts of the body.

(3) Plan of circulation of blood of the crayfish. From heart to..... From..... to..... From..... to the heart.
(a) Any veins? Any capillaries?[1]
(b) How is the circulation kept up?
(c) Why is the circulation kept up?

2. The Respiratory System.
(1) The Gills. With sharp scissors cut away the carapace from one side of the cephalothorax, exposing the white, feathery gills. Dissect under water.
(a) Number of gills attached to the base of each leg? Remove each leg with your forceps and see.
(b) Number attached to body wall?
(c) Total number on one side?
(d) Total number on both sides?
(e) What does Huxley's "Crayfish" say as to the number of gills in the English crayfish (genus Astacus)?
(f) Does our crayfish (Cambarus) have the same number of gills as the English crayfish?
(g) Use of the gills?
(h) Do you see that they are really on the outside of the body wall, *i. e.*, are external organs?
(2) Plan of the respiratory system.
(a) How connected with the circulatory system?
(b) Why connected with the circulatory system?

3. The Digestive System.
(1) Mouth-parts. (Mandibles, etc.)
(a) Name parts concerned in prehension.
(2) The Mouth. Find it with your probe.
(a) Shape?
(b) Size?
(c) Location?
(3) The Gullet. Find this short tube leading into the wide stomach. Use?
(4) The Stomach. With scalpel very carefully cut away the top of the head and expose the large, thin-walled stomach.
(a) Color?

[1] See Huxley's "Crayfish," pp. 69–74.

(b) Size?
(c) Contents? Open it and see.
(d) Use of the stomach?

(5) The Liver—large masses of reddish or brownish material posterior to the stomach.
(a) Number of lobes?
(b) Use?

(6) The Intestines. Trace them from the stomach to the vent, in the last segment of the abdomen.
(a) Straight or coiled?
(b) Use?

(7) Diagram or sketch the digestive organs and name them.

4. The Muscular System. (The Muscles.)
(1) The white meat. Where do you find it?
(2) Use to the crayfish?
(3) Use to man?

5. The Nervous System. Look for a white cord along the floor of the abdomen.
(1) Is the cord single or double?
(2) How many ganglia to a segment?
(3) How many ganglia in the abdomen?
(4) How many ganglia in the thorax?
(5) How many ganglia in all?
(6) Esophageal ganglia. Trace the nerve cord forward until it ends in a larger ganglion about the gullet. To what organs can you trace nerves?
(7) Sketch plan of nervous system.

6. The Special Senses.
(1) The Eyes. How protected?
(2) The Ears.
(a) Ear-sacs. Look for them at the base of the antennules.
(b) Size?
(c) Contents?
(d) Use?
(3) The Tongue.
(a) Any present in the mouth?
(b) Has the crayfish taste?[1]

[1] Huxley, p. 115.

(4) Organs of Sensation (Feeling).
(a) Location?
(b) Consist of what?
(c) Use?

(5) Upon what sense does the crayfish most rely? Why?

For comparison, make a study of any other crustaceans available, using the General Studies and the Morphophysiologic Study for the crayfish, making any necessary changes or omissions.

MOUNTING A CRAYFISH

Take a smooth pine board about 6 x 8 inches or larger, as the size of specimen requires. (Heavy cardboard, as suggested by Colton, will answer if boards are not available.) Bore a small hole in the center of one end of the board if you wish to hang up your specimen when mounted.

1. Draw a line the length of your crayfish down the center of the board.

2. Take a moist (not wet) crayfish, and very carefully remove and arrange in their natural order the following appendages from one side of the crayfish: One antennule, one antenna, one mandible, one metastoma, two maxillæ, three maxillipeds, five legs, and six swimmerets.

3. Temporarily pin your specimen so that the center of it from beak to telson will be over the line drawn in the center of the board, and so that the appendages not yet removed will lie in their natural position.

Now take the appendages you have removed, one at a time, beginning anteriorly, and with a small amount of Major's white cement stick each one to the board so that it lies as nearly as possible in the same position as the one not yet removed, except that instead of overlapping, the mouth-parts should lie one in front of another so as to show all the parts, and the legs and swimmerets should have their bases along the sides of the body and not under it.

When these are securely fastened down to the board, unpin the crayfish and remove the appendages from the other side, arranging them similarly on the other side of the central line and at the same distance from it.

4. Now disjoint the abdomen from the cephalothorax and with a scalpel clean out the soft parts from the interior of both. Put them together again with the median line above the line drawn in the center of the board, placing a bridge of cork or paper under the junction of the cephalothorax and the abdomen, to raise the crayfish to its natural curvature, and glue them in place.

ARACHNIDA (The Spider)

Take Morphophysiologic Study of the spider.
Take Systematic Study for Branch Arthropoda.

MORPHOPHYSIOLOGIC STUDY OF THE SPIDER

A. External Morphology

1. The Cephalothorax (head and thorax united).
   (1) Segmented or unsegmented?
   (2) Shape?
   (3) Color?
   (4) Attachment to thorax?
   (5) Its one marked peculiarity?
   (6) Appendages.
      (a) Antennæ present or absent?
      (b) Compound eyes present or absent?
      (c) Simple eyes present or absent?
         (1) Number?
         (2) Location? Show by sketch.
         (3) Color?
         (4) Shape?
         (5) Use?
      (d) Mandibles or jaws (cheliceræ).
         (1) Shape?
         (2) Number of segments?
         (3) Number of fangs?
         (4) Use?
      (e) Pedipalpi, palpi, maxillæ, or second pair of jaws present?
      (f) Mouth-parts for biting or sucking?
      (g) The legs.
         (1) Number of pairs?
         (2) Of same size, or do they vary?

(3) Number of segments to each leg?
(4) Number of clawed legs?
(5) Sketch a leg and name parts present.
(6) In what order do the legs move in locomotion? Watch a live spider and see.
(7) Covering of the legs?

(7) The Special Senses.
(a) Sight. Organs of?
(b) Touch. Organs of?
(c) Smell. Organs of?
(d) Hearing. Organs of?
(e) Taste. Organs of?
(f) Name any other senses present. Organs of?

2. The Abdomen.
(1) Segmented or unsegmented?
(2) Covering?
(3) Color above?
(4) Color below?
(5) The Spinnerets. (Use magnifying glass.)
(a) Number?
(b) Location?
(c) Use?
(6) The Lung Sacs. (Use magnifying glass.)
(a) Number?
(b) Location?
(c) Use?
(7) Tracheæ. (Use magnifying glass.) Look just in front of the spinnerets.
(a) Number?
(b) Location?
(c) Use?

INSECTA

COLLECTION OF INSECTS REQUIRED OF EACH STUDENT

ARRANGE your collection in groups to represent the following characteristics:

1. As to Mouth-parts.
   (1) Five insects having biting mouth-parts.
   (2) Five insects having sucking mouth-parts.
   (3) Three insects having mouth-parts adapted for both biting and sucking.
   (4) At least one insect having mouth-parts for lapping.
2. As to Protective Resemblance.
   (1) Five insects having general protective resemblance.
   (2) Six insects having special protective resemblance—by color, by shape, by attitude, or by any or all of these combined.
3. Mimicry. Two genuine cases of mimicry, presenting in each case both the mimic and the mimicked.
4. As to Activities.
   (1) Five crepuscular or nocturnal insects.
   (2) Five diurnal insects.
5. As to Economic Value.
   (1) Five insects which are useful to man.
   (2) Five insects which are harmful to man.
   (3) At least three specimens of insects' architecture or industry.

Temporary Insect Case.—A cigar-box with a sheet of cork or a couple of layers of coarse white blotting-paper in the bottom will serve very well for a temporary insect case for each student.

Put a few drops of turpentine or formaldehyd in one corner to keep out live insect pests. Use regular insect pins. Klaeger's Nos. 3 and 4 are perhaps the most useful sizes. They may be obtained from dealers in naturalists' supplies.

The pin, except in the case of beetles, should be passed through the thorax of the insect, one-third of the pin extending above the body. On the pin, about half-way between the insect and the cork, place a paper label giving date and locality of capture, and the name of the insect or the principle which it illustrates. Beetles should have the pin thrust through the right wing cover near the middle of the body.

Make out a "box-scheme" showing what each of your insects represents, remembering that the same specimen may belong to several of the above-mentioned groups. Write this scheme in ink on white paper and paste it on the inside of the lid before handing in your collection.

Collecting.

1. Equipment.
   (1) Killing Bottle or Cyanid Jar.
      (a) Preparation. Put about a teaspoonful of potassium cyanid, broken into bits, into a wide-mouthed bottle or a pint fruit-jar. Do not handle the cyanid with the fingers, nor breathe its fumes, as it is extremely poisonous. Pour in just enough water to cover the cyanid, then carefully pour in enough plaster-of-Paris to take up the water.
      Set the bottle, uncorked, on the outside window ledge over night. Carefully drain off any surplus water, leave it exposed to the air for a short time, and cover the plaster-of-Paris with a piece of cotton batting or a disk of paper cut to fit the jar. Cover and keep tightly closed when not in use. Label the jar "Poison."
      (b) Use. When an insect is caught in the net, uncover the cyanid jar and with one hand carefully slip it into the net and place the mouth of the jar over the insect, then, with the other hand, place the lid of the jar on the outside of the net directly under the mouth of the jar and quickly turn the jar right side up, keeping the lid over the mouth until the insect is slightly stupified, then slip the lid on the jar inside the net.
      Many times an insect at rest on stem or flower

can be readily caught in the jar by slipping the open jar below the insect and quickly knocking it into the jar with the lid.

(2) Net.

(a) Making. "For a handle to the net an old broomstick may be used. Bend a No. 3 galvanized wire into a circle about a foot in diameter, turning the ends of the wire out. A hole should be made in the end of the handle by burning it with a red hot iron, or by boring it with a small bit. Now fasten the ends of the wire firmly into this with pegs or nails. Make a cheesecloth sack a yard long, round off one corner of the bottom, and firmly sew the open end to the wire."[1]

(b) Using. In using, give the net a light, quick swing. When an insect is caught, throw the net over to one side so the insect cannot escape at the top.

Sweep the net along over the grass or the tops of bushes as you pass, and insects trying to escape will fly into the net. Instead of chasing a butterfly, follow it cautiously till it lights and quickly throw the net over it.

As to the manner of taking the insects from the net, see cyanid jar (1) (b).

(3) Care of Specimens while collecting.

If only a few insects are caught, they may be carried home in the cyanid jar, and even allowed to remain in it over night, but if very many are captured, some will be damaged by crowding, or by the struggles of those afterward put into the jar.

(a) A deep cigar-box may be used to good advantage for carrying home the insects. In the bottom of the box put a layer of sheet wadding, then a layer of glazed or tissue paper, then a layer of insects. Follow this by alternate layers of wadding and paper, and insects as needed, putting the glazed paper next to the insects.

[1] Jackson and Daugherty's "Agriculture Through the Laboratory and School Garden."

(b) For butterflies and other insects with large and beautiful wings, use separate papers as follows: Let the wings of the butterfly be folded over its back. Lay it on its side on a rectangular piece of paper. Fold the paper down over the butterfly, forming a triangle, and turn the margins over to keep the paper closed.

(4) Breeding Jar. Prepare several breeding jars for rearing insects from the eggs or larvæ. Place a couple of inches of sand or soil in the bottom of a quart fruit-jar, cover the jar with a piece of cheese-cloth, securing it in place by a small rubber band.

When insect eggs or larvæ are found, place them, together with a portion of the plant on which they are found, in the jar. Moisten the sand, but do not make it too wet, and renew the food every day.

If the plant food is too far away, or if it will be less trouble, place a small bottle of water in the bottom of the breeding jar, and keep a branch of the food-plant in it. Renew this as needed, for caterpillars are greedy, and you will need to keep a good supply of food for them.

2. Field Trip.

(1) Habitat.

(a) Look in the grass and weeds, under stones and boards and logs, and in old rotten stumps, on the bark of trees, in galls and rolled-up leaves, and especially upon any plants having leaves full of holes or with ragged edges.

(b) Look on the surface of the water of a pond or slow stream. Look in the mud along the edge, or carry some of the muddy water back in a breeding jar and let it stand for a few days. Examine to see if it contains any insect life.

(c) Look flying about in the air.

(d) What three kinds of habitats do you find occupied by insects? Why do you find certain kinds of insects in one place, and certain others in different kinds of habitats?

(2) Adaptations. What special adaptations to environment do you find?
  (a) Are some kinds of insects harder to find than others? Why?
  (b) Are some harder to capture than others? Why?
(3) Food.
  (a) Notice carefully upon what plant, and what part of the plant, each kind of insect is feeding when found.
  (b) Notice whether there are any holes in the leaves or stem of the plant, or how the plant has been affected by the insect.
(4) Effects upon Vegetation.
  (a) If there are any holes in the plant, how were they made?
  (b) In what stage of the development of the insect was the damage done?
  (c) How would you get rid of these insects, if injurious?[1]
  (d) Did you find any beneficial insects? If so, what were they, and how are they beneficial?
(5) Enemies.
  (a) Did you observe any enemies of any insect? If so, what? Why is it an enemy?
  (b) How does the insect escape or combat these enemies?
(6) What examples of insect architecture or industry did you find?
(7) Relationships.
  (a) Did you see, on your trip, any case of symbiosus among insects, or among insects and plants? If so, explain.
  (b) Did you observe any social life among insects? If so, describe.
(8) Description of the Trip.
  After reaching home, write in ink a brief description of this trip, covering the points mentioned, and hand to the teacher.

[1] See "Insecticides," Jackson and Daugherty's "Agriculture Through the Laboratory and School Garden."

3. Evening Trip.
   (1) Make a trip to the electric lights in the evening and you will find many beetles, moths, and bugs; or watch for the "hawk-moths" about the phlox and nasturtium beds.
   (2) Spread for bait a thick syrup of brown sugar upon the bark of tree trunks, at night. Carry a lantern and go from one tree to another, looking carefully for the moths. Quickly put the mouth of the cyanid jar over the moth while it is feeding.

Care of the Specimens.—1. Spreading Board. The wings of the larger specimens will need to be spread before they dry out. For this purpose, take a soft pine board, cover it with a coarse blotting-paper or a sheet of cork. In each side of the center of the board tack four or five thicknesses of blotting-paper, leaving a space of about one-half inch in the center of the board as a groove for the body of the insect.

Thrust an insect pin through the thorax and pin the body in this groove. By pushing against a strong vein with a pin (not with the fingers or you will spoil the beauty of the specimen) arrange the wings so that the posterior margins are at right angles to the body, and the anterior margins of the posterior wings barely touching them. Fasten them down by pinning narrow strips of paper over them near the body and allow them to remain so for a few days.

2. Moistening Jar. If the specimens get dry before you have mounted them, do not attempt to mount them until they have been relaxed by placing them for a day or two in a closed glass jar with a layer of wet sand covered with a dry paper in the bottom.

3. The Permanent Insect Case must be very tight fitting and covered with glass. A sheet of cork should line the bottom, and the appearance is greatly improved by covering this cork with white paper.

LIFE-HISTORY

Suggestion.—To make sure of an entire life-history of an insect, if the time is short, place a "blue-bottle" or "blow-fly" in a breeding jar with a piece of meat on which to lay its eggs. Watch closely as soon as the eggs are laid. The complete

development from egg to adult requires only about two weeks, and for this reason the fly makes a good study.

Plant-feeding caterpillars are less repulsive, and the cabbage butterfly develops in a few weeks and makes an interesting study; but try any and everything you find.

1. Development.
   (1) Watch the development of the eggs or larvæ in the breeding jar from day to day, and make note of every change.
   (2) If you can get them, save a specimen in each stage of the development for your collection. (Place the larvæ in a solution of formaldehyd.)
   (3) What is the duration of each stage of development? What is the name of each stage?
   (4) Sketch each stage in your notebook.
2. Activities.
   (1) Observe and describe the following activities:
      (a) Eating.
      (b) Crawling or walking.
      (c) Molting of the larvæ.
      (d) The spinning of a cocoon, or the forming of a pupa-case.
   (2) Questions.
      (a) Is the insect herbivorous or carnivorous?
      (b) How does it obtain its food in each stage of its existence—by biting, sucking, or lapping?
      (c) Does it avoid or choose the light?
3. Economic Importance.
   (1) In what stage, if any, is it injurious to vegetation?
   (2) How would you get rid of it if injurious?
   (3) Does it prey upon any other insects in any stage of its development? Is it preyed upon by any other insect?
4. Intelligence.
   (1) State at least three instincts which you have seen displayed by this insect.
   (2) Have you seen any intelligent action? If so, what?
   (3) Try an original experiment to see if you can make this insect choose to act in a way different from the usual one. Record your results.

SPRAYS AND SPRAYING

There are three classes of pests which may be combated by spraying: fungi, sucking insects, and biting insects. For spraying fungi, Bordeaux mixture has long been used with success. The only objection to it is on account of its tendency to injure tender foliage and the delicate skin of young fruit. On account of this, lime sulphur is often used as a fungicide in spraying. After July 1 the skin of apples is smoother and firmer and not so easily injured by the Bordeaux. Bordeaux is recommended also for apple scab, the spray to be applied just before the blossoms open. Bordeaux is a fungicide only, having no effect upon insects, while lime sulphur acts as both a fungicide and a contact insecticide.

Insects having sucking mouth-parts are not affected by arsenic sprays, since poison placed upon the surface of the plant is not taken into the stomach with the food. These insects must be killed by contact insecticides.

Biting insects may be poisoned by arsenic sprays, since they chew and swallow the food.

Formulas for Spraying Mixtures

Fungicides.

Bordeaux mixture:

Quick lime, 3 to 6 pounds.
Copper sulphate, 3 to 6 pounds.
Water, 50 gallons.

Dissolve the copper sulphate in water in an earthen jar or wooden pail and dilute to about thirty gallons. Slake the lime, which must not be partially air-slaked, and add to it twenty gallons of water. Now mix the two solutions thoroughly and strain through a wire-cloth strainer into the spray tank. Two pounds of arsenate of lead may be added to this mixture if wanted for an insecticide.

Lime sulphur (for spraying against San José scale):

Commercial lime sulphur, 1 gal.
Water, 8 to 12 gal.

For summer spraying of apples:

Lime sulphur, 1 gal.
Water, 30 to 40 gal.

Contact insecticides.

Kerosene emulsion:

Soap, ½ pound.
Kerosene, 2 gal.
Rain water, 1 gal.

Shave the soap and dissolve it by boiling in water. Pour the soap solution, while boiling hot, into the kerosene and churn vigorously by pumping the liquid back and forth with a force pump until it looks like buttermilk. Keep this stock solution tightly sealed. Before using dilute with from ten to twenty parts of water.

Nicotin sulphate or blackleaf 40:

Blackleaf 40, ¾ pt.
Soap, 3 lbs.
Water, 100 gal.

This solution will be found valuable for spraying plant lice or other soft-bodied insects. The soap may be omitted and then the spray may be used with lime sulphur or with Bordeaux mixture.

Insecticides for biting insects.

Paris green:

Paris green, 1 lb.
Quick lime, 2 lbs.
Water, 100 to 300 gal.

Paris green may be combined with Bordeaux mixture, but never with lime sulphur. It should never be used on peach foliage. Paris green may be applied also as a dust, mixing one pound of poison to twenty pounds of cheap flour.

Arsenate of lead:

Arsenate of lead, 2 lbs.
Water, 50 gal.

In spraying for *Curculio* on apple or plum, just after the blossoms fall, use three pounds to fifty gallons of water.

Hellebore:

Hellebore, 1 lb.
Water, 25 gal.

This spray is especially useful when the fruit—cherry, gooseberry, or currant—is ripening, since it soon loses its poi-

sonous character when exposed to the air. For this reason care should be taken to get it fresh or it will have no effect.

Spraying Exercise.—Compute the proportions required for one gallon of an arsenic spray and of one contact insecticide. Carefully prepare each. Spray any plants you find infested by insects with the kind which the condition of the plants leads you to think is required. Examine these plants in a day or two and record results. Also place a sprig of the plant sprayed with each insecticide in separate breeding jars. Label each and compare results.

Insect Studies

Note.—For a first morphologic study, use large grasshoppers and take all of the External and Internal Morphology. Then follow this with the Systematic Study for Arthropod Branch Characteristics; follow this with the Class and the Ordinal Study. The grasshopper belongs to Branch, Arthropoda; Class, Insecta; Order, Orthoptera.

For other insects, follow the same plan as for the grasshopper, omitting any questions which do not apply to the insect in hand. The Internal Morphology may also be omitted. This plan will give a comparative study of insects, showing their morphology, and bringing out the principles of classification for the branch, class, and orders to which the insects belong.

The student will notice that all insects belong to the same branch and class, but to different orders. Notice carefully the branch characteristics and then the class characteristics. Upon what is the classification based? Is it structure? Is it plan of structure? Is it development?

THE GRASSHOPPER

Morphophysiologic Study

A. External Morphology

I. **The Skeleton.**

1. Is the skeleton external or internal?
2. Character or composition?
3. Uses?

II. **Body Divisions.**

1. The Head.
   (1) Its shape?
   (2) Its size compared with the body?
   (3) Its color?
   (4) Its mode of attachment to the thorax?
   (5) Its one marked peculiarity?
   (6) The Antennæ, or Feelers.
      (a) Number?
      (b) Shape?
      (c) Location on the head?
      (d) Number of segments?
      (e) Use?
   (7) The Compound Eyes.
      (a) Number?
      (b) Shape?
      (c) Sessile or stalked?
      (d) Location on head?
      (f) Color?
      (g) Use?
   (8) The Simple Eyes.
      (a) Number?
      (b) Shape?
      (c) Color?
      (d) Location on head?
      (e) Use?
   (9) The Labrum, or Upper Lip.
      (a) Shape?
      (b) Color?
      (c) Size?
      (d) Motion?
      (e) Use?
   (10) The Mandibles are just below the labrum.
      (a) Shape?
      (b) Size?
      (c) Color?
      (d) Number?
      (e) Use?

(11) The Maxillæ, or little jaws, are just below the mandibles.
  (a) Shape?
  (b) Size?
  (c) Color?

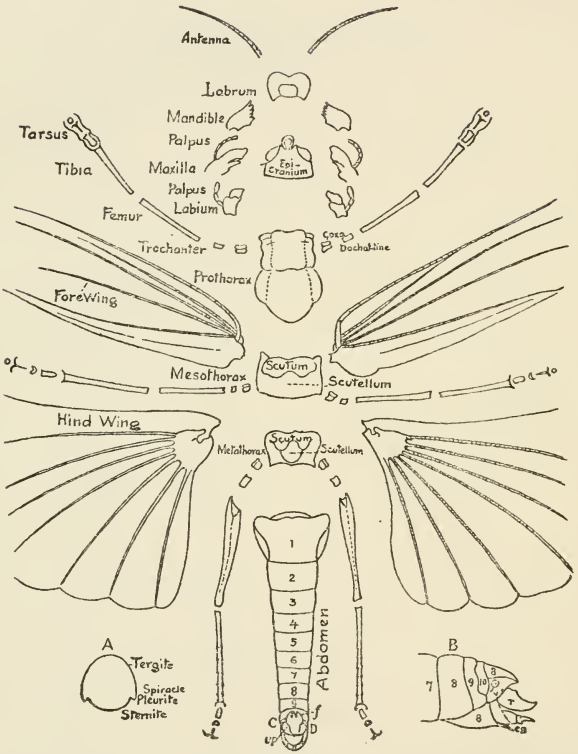

Fig. 2.—External anatomy of *Calopetnus spretus*, the head and thorax disjointed: *up*, Uropatagium; *f*, furcula; *c*, cercus. (Drawn by J. S. Kingsley.) (From Packard's Zoölogy.)

  (d) Number?
  (e) Use?
(12) The Maxillary Palpi.
  (a) Number on each side?

(b) Number of segments to each palpus?
(c) Motion?
(d) Use?

(13) The Labium, or Lower Lip.
(a) Shape?
(b) Color?
(c) Size?
(d) Motion?
(e) Use?

(14) The Labial Palpi.
(a) Number on each side?
(b) Number of segments to each palpus?
(c) Motion?
(d) Use?

(15) Sketch front or side view of the head, much enlarged. Show all the parts you can.

(16) Mouth-parts. Remove the mouth-parts from one side and sketch.
(a) Mouth-parts adapted for (1) sucking or (2) biting?
(b) Mouth-parts united into tube or free?
(c) Why so many or so few parts, as the case may be?

2. The Thorax.
(1) Shape?
(2) Size compared with the head?
(3) Size compared with the abdomen?
(4) Number of spiracles?
(5) Covering?
(6) Divisions. In the grasshopper the thorax has three divisions.
(a) The Prothorax or cape, as seen in the grasshopper, just back of the head.
(1) Shape?
(2) Color?
(3) Number of appendages, as legs or wings?
(4) Number of spiracles, if any?
(b) The Mesothorax just posterior to the prothorax. Same questions as for prothorax.
(c) The Metathorax.
Same questions as for the prothorax.

(7) The Legs.
  (a) Number of pairs?
  (b) Are they of the same size, or do they vary?
  (c) The segments in order, beginning at the body of the grasshopper, are: coxa, trochanter, femur, tibia, tarsus of foot. Sketch one leg, much enlarged, and name the parts present.
  (d) Compare first pair of legs with second pair, segment for segment, noting similarities and differences.
  (e) Compare second and third pairs.

(8) The Wings.
  (a) Number?
  (b) Location?
  (c) Color above?
  (d) Color below?
  (e) Covering scaly, smooth, or hairy?
  (f) Anterior and posterior wings equal in size?
  (g) Anterior and posterior wings of same thickness?
  (h) How folded when at rest? When in motion?
  (i) Wings analogous or homologous to the wings of a bird?
  (j) Sketch the wings extended, putting in all the markings.

3. The Abdomen.
  (1) Shape?
  (2) Size compared with the thorax?
  (3) Covering?
  (4) Number of segments?
  (5) Ovipositor present or absent?
  (6) The Sting present or absent?
    (a) Why?
    (b) Why not found in all insects?
  (7) Tympana, on first abdominal segment of the grasshopper. If your specimen is not a grasshopper, you may have to look elsewhere for them. If you do not find them, consult a large work on insects (Kellogg or Comstock).
    (a) Size of tympana?
    (b) Number?

(c) Use?
(d) Color?
(8) The Spiracles.
(a) Number to each segment?
(b) Total number?
(c) Use?
(9) Sketch the abdomen, much enlarged. Name the parts present.

B. Internal Morphology

Pin a large female insect down in a wax-bottomed pan or on a soft pine board, dorsal side up. Dissect under water. With sharp scissors carefully cut through the body wall of the abdomen and expose the internal organs by removing the upper portion of the body wall. Use a fresh specimen.

1. The Circulatory System. Cut forward along the dorsal side and find small tubular organ called the heart.
(1) Trace it.
(2) Sketch it.
(3) Plan of grasshopper's circulatory system.
(a) Any arteries, veins, capillaries?
(b) Closed or open circulation?
2. The Respiratory System.
(1) The air-sacs in grasshoppers are tiny white sacs along the sides of the abdomen.
(a) How many to each segment? Remove the dorsal wall and see.
(b) How many in all?
(c) Uses?
(2) The tracheæ are white branching tubes.
(a) How are they connected with the air-sacs?
(b) Uses?
(3) Plan of respiratory system.
(a) Is it connected with the circulatory system?
(b) If so, how?
(c) If so, why?
3. The Reproductive System.
(1) In a female specimen you will generally find the yellow eggs in rows on each side.

(a) How many rows?
(b) How many eggs (ova) in one row?
(c) How many ova in all?
(d) If each ovum had matured into a grasshopper, how many individuals would have descended from this insect in five years, barring accidents to the ova or to the young?

(2) Trace oviduct to ovipositor.

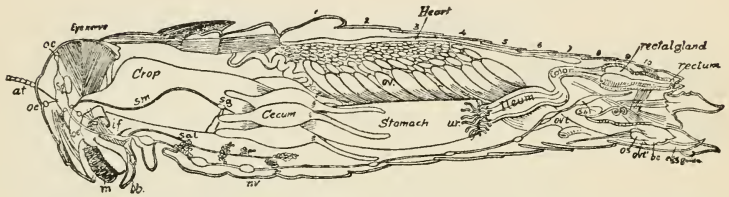

Fig. 3.—Internal anatomy of *Caloptenus femur-rubrum: at*, antenna and nerve leading to it from the "brain" or supra-esophageal ganglion (*sp*); *oc*, ocelli, anterior and vertical ones, with ocellar nerves leading to them from the "brain"; *œ*, esophagus; *m*, mouth; *lb*, labium or under lip; *if*, infra-esophageal ganglion, sending three pairs of nerves to the mandibles, maxillæ, and labium respectively (not clearly shown in the engraving); *sm*, sympathetic or vagus nerve, starting from a ganglion resting above the esophagus, and connecting with another ganglion (*sg*) near the hinder end of the crop; *sal*, salivary glands (the termination of the salivary duct not clearly shown by the engraver); *nv*, nervous cord and ganglia; *ov*, ovary; *ur*, urinary tubes (cut off, leaving the stumps); *ovt*, oviduct; *sb*, sebaceous gland; *bc*, bursa copulatrix; *ovt'*, site of opening of the oviduct (the left oviduct cut away); 1–10, abdominal segments. The other organs labeled in full. (Drawn from his original dissections by Mr. Edward Burgess.) (From Packard's Zoölogy.)

4. The Digestive System.
(1) The Mouth.
(a) Location?
(b) Shape?
(c) Size?
(d) Mouth-parts present?
(2) The Tongue.
(a) Shape?
(b) Size?
(c) Color?
(d) Use?

(3) The Esophagus, a short tube leading into the crop.
Use?

(4) The Crop. Note where the esophagus begins to enlarge.
(a) Size?
(b) Shape?
(c) Use?

(5) The Salivary Glands, grape-like or mulberry-like clusters about the crop.
Use?

(6) The Gastric Ceca (in the grasshopper) are small worm-like appendages back of the crop.
(a) Number?
(b) To what attached?
(c) Use?

(7) The Stomach. Just back of the gastric cæca the alimentary canal enlarges into the true stomach.
(a) Shape?
(b) Size?
(c) Use?

(8) The Malpighian Tubes are long, small, tubular organs at the posterior end of the stomach.
(a) Color?
(b) Size?
(c) Shape?
(d) Use?

(9) The Intestines.
(a) Straight or coiled?
(b) Use?
(c) In what segment do they terminate?

(10) Diagram or sketch the alimentary tube of the grasshopper, and name its parts in order from the mouth to the vent.

5. The Nervous System. Look for a white cord along the floor of the abdomen.

(1) Is the cord single or double?
(2) How many ganglia to a segment?
(3) How many ganglia in all?
(4) Trace nerves to the legs.

(5) Trace nerves to the wings.
(6) Trace nerves to the eyes.
(7) The Special Senses.
(a) The eyes.
(1) Kind?
(2) Location?
(b) The ears.
Location?
(c) The tongue.
Taste dull or acute?
(d) Organs of smell.
Location?

THE BUTTERFLY

Morphophysiologic Study

1. Skeleton.
(1) External or internal?
(2) Character?
(3) Outgrowths or covering.
(a) Of the body?
(b) Of the wings?
2. The Head.
(1) Shape?
(2) Antennæ.
(a) Shape? How do they differ from those of the moth?
(b) Location on head?
(c) Number of segments?
(d) Use?
(3) Compound Eyes.
(a) Number?
(b) Shape?
(c) Sessile or stalked?
(d) Location on the head?
(e) Color?
(f) Use?
(4) Mouth-parts. The mouth-parts are rather difficult for the beginner to identify.
(a) The proboscis, or sucking organ, is a long coiled tube composed of the modified maxillæ.

(b) Labial palpi. Look on each side of the sucking tube for the jointed appendage.
(1) How many segments?
(2) Are the palpi naked or hairy?

3. The Thorax.
(1) How does it differ from the thorax of the grasshopper?

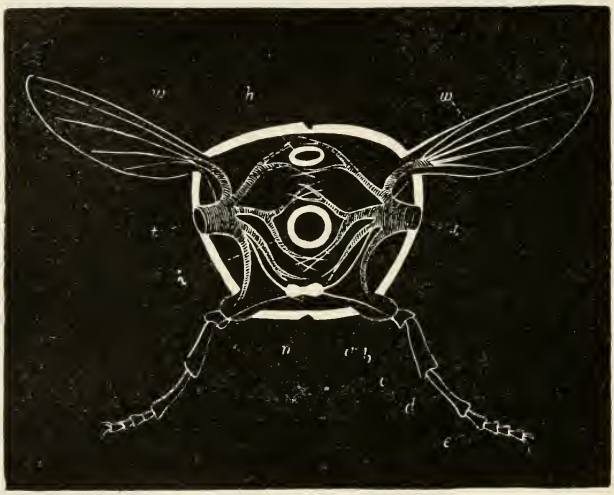

Fig. 4.—Ideal transverse section of an insect: *h*, Dorsal vessel; *i*, intestine; *n*, ventral nerve-cord; *t t*, stigmata leading into the branched tracheal tubes; *w w*, wings; *a*, coxa of one leg; *b*, trochanter; *c*, femur; *d*, tibia; *e*, tarsus. (After Packard.)

(2) The Wings.
(a) Number?
(b) Location?
(c) Color above? Below?
(d) Any differences between anterior and posterior wings? If so, what?
(e) How folded when at rest?
(f) Covered with scales, naked, or hairy? Place a portion of a wing under the microscope, and draw several scales. Do you find any transparent spots where the scales have rubbed off?

(3) The Legs.
(a) Number of pairs?
(b) Size. Are they equal in size, or do they vary?
(c) Compare the first pair with the second and third pairs, segment for segment.

4. Abdomen.
(1) Shape and size as compared with that of the grasshopper? As compared with that of the moth?
(2) Covering?
(3) Number of segments?
(4) Ovipositor present or absent?
(5) Sting present or absent? Why?

5. Metamorphosis.
(1) Complete or incomplete?
(2) Larvæ called what?

THE HONEY-BEE OR THE BUMBLE BEE

Morphophysiologic Study

1. Covering.
What is the character of the covering of the head and thorax?

2. Antennæ.
(1) Number?
(2) Location?
(3) Is there any peculiarity about the antennæ? If so, what?

3. Compound Eyes.
(1) Size?
(2) Location?

4. Simple Eyes.
(1) Locate the three simple eyes.
(2) How are they arranged?

5. Mouth-parts.
(1) Mandibles.
(a) Are they adapted for digging or for molding wax?
(b) Shape?
(2) Proboscis. Pick apart the proboscis and identify.
(a) The elongated labium.

(b) The maxillæ, the two blades above the tongue.
(c) The slender labial palpi below the tongue.

6. The Wings.
   (1) Are the posterior and anterior pairs equal in size?
   (2) How are the wings arranged when at rest? When in motion?
   (3) What peculiarities about them?
   (4) Are the wings thick and opaque or membranous and transparent?
7. The Legs.
   (1) Are the legs alike?
   (2) Compare the posterior legs, segment for segment, with those of the grasshopper.
   (3) What special adaptation do you find in the tibiæ?
   (4) How do the basal joints of the tarsi differ from those of the other legs?
   (5) For what are the cutting edges between the two large segments adapted?
8. The Abdomen.
   (1) Shape?
   (2) Segments?
      (a) Number?
      (b) What is the peculiarity of the anterior segment?
      (c) Of the second anterior segment?
      (d) Can the abdomen be bent under the thorax? If so, purpose?
   (3) The Sting. If your specimen is a female, examine and describe the sting.
      Why has the male no sting?

THE HOUSE FLY

Morphophysiologic Study

In this study a good magnifying glass or dissecting microscope will be needed.

1. How are the head and thorax united? The thorax and the abdomen?
2. With what is the body covered?

3. Head.
   (1) Antennæ.
      (a) Location?
      (b) Number of segments?
      (c) Use?
   (2) Compound Eyes.
      (a) Location?
      (b) Size?
      (c) Shape of facets?
   (3) Simple Eyes.
      (a) Location?
      (b) Number?
   (4) Mouth-parts. Straighten out the proboscis which is bent back under the head, and examine it with a good dissecting microscope or with the low power of a compound microscope.
      (a) The tongue is the labium modified or the under lip, and the divisions at its end are the labial palpi. Are they smooth or rough?
      (b) Mandibles. On the head near the base of the tongue look for the slender, rudimentary mandibles.
      (c) Maxillary Palpi. On the shaft of the tongue find the hairy, segmented maxillary palpi.
      (d) Sketch the mouth-parts as you see them. Compare with a good cut and name the parts shown in your figure.
      (e) Are the mouth-parts adapted for biting, sucking, or lapping?
4. Thorax.
   (1) Wings.
      (a) How many developed wings?
      (b) How are they arranged when at rest? Show by sketch.
      (c) Look behind the wings for a pair of scales or membranes—the alulets.
      (d) Under the alulets look for a pair of pin-like appendages ending in a knob. These are called "balancers," and it is believed that their function is sensory.

(1) What organs in man are the "balancers" or the organs of the sense of equilibrium?
(2) Sketch the alulets and the "balancers" as you see them.

(2) The Legs.
(a) Are they alike?
(b) Are they fitted for running or for jumping?
(c) Are there any hooks or pads on the feet? If so, of what use are the pads?
(d) How does the fly walk on the ceiling? Can the grasshopper, beetle, or crayfish walk on the ceiling?

5. Abdomen.
(1) Shape?
(2) Size?
(3) Number of segments?
(4) Ovipositor or sting present?

HEMIPTERA

The Squash Bug, or the Cicada

The bugs, cicadas, squash bugs, plant lice, etc., have a sucking beak. The mandibles and maxillæ appear as slender, bristle-like organs, for which the lower lip forms a sheath.

1. The Sucking Beak. Look on the ventral side for the beak. Examine it with a glass and make out the following parts:
(1) Sheath formed of lower lip.
(2) Mandibles and maxillæ, four slender bristle-like organs within the sheath.

2. Wings. Do you find half of the anterior wings hardened, as the name (*hemi*, half, *pteron*, wing) indicates?

3. Insecticide. The aphides, or plant lice, and the scale insects belong to this order. Would you exterminate them by poison insecticide, contact insecticide, or by a "smudge"?

Prepare several spraying solutions (see pages 66 and 68) and experiment with them upon plants infested with plant lice or squash bugs. Be careful not to have the solutions too strong. Record and explain results.

THE BEETLE[1]

Morphophysiologic Study

External Morphology

I. **The Skeleton.**
1. Is the skeleton external or internal?
2. Character or composition?
3. Uses?

II. **Body Divisions.**
1. The Head.
   (1) Its shape?
   (2) Its size compared with the body?
   (3) Its color?
   (4) Its mode of attachment to the thorax?
   (5) Its one marked peculiarity?
   (6) The Antennæ, or Feelers.
      (a) Number?
      (b) Shape?
      (c) Location on the head?
      (d) Number of segments?
      (e) Use?
   (7) The Compound Eyes.
      (a) Number?
      (b) Shape?
      (c) Sessile or stalked?
      (d) Location on head?
      (f) Color?
      (g) Use?
   (8) The Simple Eyes, if present.
      (a) Number?
      (b) Shape?
      (c) Color?
      (d) Location on head?
      (e) Use?
   (9) The Labrum, or Upper Lip.
      (a) Shape?
      (b) Color?

[1] See Fig. 119 of Part II, "Principles of Economic Zoölogy."

(c) Size?
(d) Motion?
(e) Use?

(10) The Mandibles.
(a) Shape?
(b) Size?
(c) Color?
(d) Number?
(e) Use?

(11) The Maxillæ.
(a) Shape?
(b) Size?
(c) Color?
(d) Number?
(e) Use?

(12) The Maxillary Palpi.
(a) Number on each side?
(b) Number of segments to each palpus?
(c) Motion?
(d) Use?

(13) The Labium, or Lower Lip.
(a) Shape?
(b) Color?
(c) Size?
(d) Motion?
(e) Use?

(14) The Labial Palpi.
(a) Number on each side?
(b) Number of segments to each palpus?
(c) Motion?
(d) Use?

(15) Sketch front or side view of the head, much enlarged. Show all the parts you can.

(16) Mouth-parts. Remove the mouth-parts from one side and sketch.
(a) Mouth-parts adapted for (1) sucking or (2) biting?
(b) Mouth-parts united into tube or free?
(c) Why so many or so few parts, as the case may be?

2. The Thorax.
   (1) Shape?
   (2) Size compared with the head?
   (3) Size compared with the abdomen?
   (4) Covering?
   (5) Divisions. In the grasshopper the thorax has three divisions. Has this insect's thorax three divisions?
   (6) The Legs.
      (a) Number of pairs?
      (b) Are they of the same size, or do they vary?
      (c) The segments in order, beginning at the body are: coxa, trochanter, femur, tibia, tarsus, or foot. Sketch one leg, much enlarged, and name the parts present.
      (d) Compare first pair of legs with second pair, segment for segment, noting similarities and differences.
      (e) Compare second and third pairs.
   (7) The Wings.
      (a) Number?
      (b) Location?
      (c) Color above?
      (d) Color below?
      (e) Covering scaly, smooth, or hairy?
      (f) Anterior and posterior wings equal in size?
      (g) Anterior and posterior wings of same thickness?
      (h) How folded when at rest? When in motion?
      (i) Wings analogous or homologous to the wings of a bird?
      (j) Sketch the wings extended, putting in all the markings.
3. The Abdomen.
   (1) Shape?
   (2) Size compared with the thorax?
   (3) Covering?
   (4) Number of segments?
   (5) Ovipositor present or absent?
   (6) Sting present or absent?
      (a) Why?
      (b) Why not found in all insects?

(7) Sketch the abdomen, much enlarged. Name the parts present.
(8) Metamorphosis complete or incomplete? Stages called.....

SYSTEMATIC STUDY FOR BRANCH ARTHROPODA

Use many different arthropoda for this study.

1. The Body.
   (1) Segmented or unsegmented?
   (2) Symmetry?
   (3) Body cavities. One, the hæmal. What systems does it contain?
   (4) The external skeleton (exoskeleton).
      (a) Of what does it consist?
      (b) Use?
2. The Appendages or Limbs.
   (1) Segmented or unsegmented?
   (2) Number?
   (3) Called what?
   (4) Position on the body?
   (5) Use?
3. It belongs to Branch Arthropoda because it has the following Arthropod branch characteristics: (Name the characteristics you have discovered and compare with those given in the text.)

SYSTEMATIC STUDY FOR THE CLASSES OF ARTHROPODA

(Use a crayfish, an insect, a spider, and a "thousand-legs.")

1. Shape of each?
2. Number of segments in each?
3. Body divisions.
   (1) Do they show any body divisions?
   (2) If so, are they divided into head, thorax, and abdomen, or into cephalothorax and abdomen?
4. Covering of each.
   If any, called what?
5. Antennæ wanting, or one or two pairs?
6. Eyes. Compound, simple, or both?

7. Appendages.
   (1) How many, and what?
   (2) If there are body divisions, how many appendages are there—
      (a) On the thorax or cephalothorax?
      (b) On the abdomen?
8. Respiration. By means of what?
9. This arthropod has the following class characteristics: (Name the characteristics you have discovered and compare with those given in the text.) Hence, it belongs to Class.....

ORDINAL STUDY FOR CLASS INSECTA

Use insects of different orders for this study.

1. Mouth-parts.
   Are they adapted for biting, sucking, or lapping, or for any two of these processes?
2. Thorax.
   (1) Are the divisions prothorax, mesothorax, and metathorax distinct?
   (2) If not, how do you account for differences discovered?
   (3) Wings.
      (a) Number?
      (b) Shape?
      (c) Membranous, thick, or scaly?
      (d) Similarity.
         (1) If there are two pairs, are the anterior and posterior pairs equal in size?
         (2) Are they of the same thickness?
      (e) Covering. Naked or covered with hairs or scales?
      (f) Position.
         (1) Folded when at rest? If so, how?
         (2) Folded when in motion?
      (g) Any other ordinal characteristics of wings?
   (4) The Legs.
      (a) Strong or weak? Why?
      (b) Similarity.
         (1) Are the legs alike in shape and size?
         (2) Any adaptations?
      (c) Feet. Clawed? Padded?

3. The Abdomen.
   (1) Shape?
   (2) Number of segments or somites?
   (3) Any appendages of the abdomen, as the ovipositor, sting, or some other appendages peculiar to this order?
   (4) Any other ordinal peculiarity?
4. Metamorphosis.
   (1) Complete or incomplete?
   (2) Larval stage called what?
5. Odor. Any distinctive odor?
6. This insect has the following ordinal characteristics: (Name those you have discovered—see text for ordinal characteristics.) Hence, it belongs to Order.....

See descriptive zoölogies for the Orders of Insects.

COMPARATIVE SYSTEMATIC STUDY

(See page 110.)

For this study the teacher should select a dozen or more different insects representing a number of orders, but he should have several insects belonging to each order represented, such as grasshoppers, crickets, and walking-sticks; butterflies and moths; giant water-bugs, chinch-bugs, and cicadas; fire-flies, June-bugs, and lady-beetles; wasps, honey-bees, and bumble-bees.

Let the student write a brief description of each insect, placing each characteristic in the column designated on page 110.

When this is completed, check thus (*) all the points in the description which are the same for all insects, and compare them with the class characteristics given in the text or in some good work on insects.

Check thus (†) all points which agree for several insects, and thus (‡) those which are alike for several others, and thus (x) for those of others.

Compare those points in which all the insects in each small group agree with the ordinal characteristics given in some work on insects, or in the text, for the orders represented.

CHARACTERISTICS

Name of Insect	Body Divisions	Antennæ	Eyes	Mouth-parts Present	Thorax	Legs	Feet	Wings	Abdomen	Metamorphosis	Larvæ	Respiration
		Number? Segments?	Simple or Compound or both?	Adapted for biting, sucking, or lapping?	Divisions Distinct?	Number? Location? Similarity? Strong or Weak? Special Adaptions?	Hooked or Padded? Large or small?	Number? Location? Character? How folded or arranged? Anterior and posterior pairs similar? Covering?	Paired Appendages? Ovipositor, or Sting?	Complete?	Called what?	By what?
Grasshopper												
Cricket												
Moth												

PISCES (THE FISH)

TAKE the Study of a Live Fish.

Take all applicable points of General Studies, I, II, III.

Take Special Morphophysiologic Study.

Take Systematic Study for Branch Chordata and Class Pisces. See p. 128.

Take Final Study.

Give your best definition of a fish.

Make an oral recitation of ten minutes on fishes.

Write a theme on the fish, using, in connected form, the facts you have gathered in your studies. Illustrate with good sketches.

STUDY OF A LIVE FISH

1. **Collecting.** If fishes are studied in a suitable season, each student should be required to capture and bring to the laboratory at least *one live fish*, reporting on the following outline:

(1) Habits and habitat.

(a) Does the kind of fish you caught live in shallow or deep water? Why?

(b) Does it live in still or running water? Why?

(c) In clear or muddy water? Why?

(d) Does it live near the surface, or at the bottom of the stream?

(e) Does it move slowly or swiftly?

(f) Is it a "game" fish or is it easy to capture?

(g) Did you fish with pole or with trot-line? In the daytime or at night?

(h) Is this fish solitary or gregarious?

(i) What is a company of fishes called?

(2) Food. Use various kinds of bait.

(a) What kinds of fish did you catch with each kind of bait?

(b) Is this fish carnivorous, herbivorous, or omnivorous?

(c) Does this fish feed in the daytime or in the evening and at night?

(3) Concealment.

(a) Where does this fish hide?

(b) For what purpose or purposes does it hide?

(c) Has it any *natural means* of concealment? If so, what?

(4) Senses.

(a) What evidences have you as to whether or not fishes can hear?

(b) Evidences that they can smell?

(c) Evidences that they see?

2. Laboratory Study.

(1) Locomotion.

(a) Just how is locomotion accomplished by this fish? What fin or fins are most used in locomotion?

(b) Experiment and find out the use of the paired fins.

(1) Keeping the fish under the water, pass a rubber band over the pectoral fins so as to hold them close against the body.[1] What effect does this have upon the position of the body?

(2) Same as (1) for the ventral fins.

(2) Respiration.

(a) Watch the movements of the mouth and gill covers.

(b) Experiment and find out whether the water moves over the gills and out through the mouth, or in at the mouth and out over the gills.

(3) Feeding. Try several kinds of food.

(a) Does it have any choice? If so, by what *sense* does it choose its food?

(b) Feed it at various times in the day or night. Results?

(c) How does it take its food?

(4) Senses.

(a) Experiment and find out whether it sees or hears you first. Which of these senses is of the greatest value in warning it of danger?

(b) What is its range of sight?

(c) Does it ever close its eyes or wink? Why?

(d) Has it any voice or song? Why?

[1] Colton's "Practical Zoölogy."

(e) Have you found any evidence that the fish can taste?
(f) Where is the fish most sensitive to touch? Is it sensitive to a jarring or stirring of the water if there is no sound?

(5) What means of defense has this fish?
(6) Do fishes ever play?
(7) Do they ever sleep?

THE SUNFISH

Morphophysiologic Study

A. External Morphology

1. Shape? Use of this particular shape to the sunfish?
2. Length of sunfish from tip of nose to caudal fin?
3. Thickness.
   (1) Laterally?
   (2) Dorsoventrally?
   (3) Is it compressed or flattened?
4. Covering. Naked, ctenoid scales, or cycloid scales?
5. Dorsal surface.
   (1) Shape?
   (2) Color?
6. Ventral Surface.
   (1) Shape?
   (2) Color? Why this difference in color?
7. The Fins.
   (1) Paired Fins.
      (a) Number?
      (b) Use?
   (2) Unpaired Fins.
      (a) Number?
      (b) Use?
   (3) Caudal Fin. Is it homocercal[1] or heterocercal[1]?
8. Nostrils.
   (1) How many nostrils has the sunfish?
   (2) Do they open into the mouth? (Thrust a tipped bristle or a flexible probe into the nostrils and see.)
   (3) Use of the nostrils to the fish?

[1] See Glossary, Part II, "Economic Zoölogy."

9. The Eyes.
   (1) How many?
   (2) Location?
   (3) Parts of eye present as compared with your own?
   (4) Parts wanting as compared with your own?
   (5) Why these differences?
10. The Ears.
   (1) Do you find any evidences of external ears?
   (2) If not, why not?
   (3) Does the fish hear? State your proof.
11. The Mouth.
   (1) Size?
   (2) Shape?
   (3) Position?
12. The Gill Covers.
   (1) Position?
   (2) Use?
13. The Gill Openings.
   (1) Position?
   (2) Use?
   (3) Number?
14. The Scales.
   (1) Number of rows from dorsal to ventral edge?
   (2) Number in one row from side of head to caudal fin?
   (3) Estimate the total number of scales on the entire fish.
   (4) How are the scales fastened into the skin?
   (5) Are the scales naked or covered with a membrane?
   (6) Is the pigment in spots or is it uniformly distributed? Use of the pigment?
   (7) Are the scales ctenoid or cycloid[1]?
   (8) Examine a scale with hand lens or microscope. Sketch one (enlarged five or ten times) to show its structure.
15. The Lateral Line.
   (1) How do the scales of the lateral line differ from those of other parts of the body?
   (2) Use of lateral line?

16. Sketch. Turn the specimen with its unmutilated side toward you and sketch a side view of it, locating the mouth,

[1] See Part II, "Economic Zoölogy," Figs. 173, 174.

nostrils, ear, eye, gills, fins, lateral line, and vent. Number these points in your sketch and write these numbers and the names below it.

17. The Skin. With sharp scissors cut through the skin, and with forceps peel off a portion of it so as to expose the flesh or muscles.

(1) Is the skin thick or thin?
(2) How is it fastened to the flesh?
(3) Use?

18. The Muscles.

(1) How are they arranged on the body?
(2) Estimate what proportion of the whole fish is muscle.
(3) Why so much muscle?
(4) Are there any nerves in the muscles? Use?
(5) Do you see any blood-vessels in the muscles? Use?

19. The Respiratory Organs.

(1) Raise the gill cover and count the gills. How many?
(2) Color?
(3) How are the gills connected with the mouth?
(4) How many gill arches?
(5) How many gill filaments on one arch? How many in all? Use?
(6) What does the fish breathe? How does it obtain it?
(7) How does the water, with the air mechanically mixed with it, pass over the gills; from the mouth back over the gills, or through the gill openings forward and out at the mouth?

B. Internal Morphology

1. The Digestive Organs. Cut forward from the vent to the gills and remove the muscles from one side of the body, exposing the internal organs. Is the body-cavity large or small?

(1) Peritoneum.
  (a) Color?
  (b) Surface rough or smooth? Why?
  (c) Use?

(2) The Liver.
  (a) Size?
  (b) Shape?
  (c) Position?
  (d) Number of lobes?
  (e) Gall-bladder.
    (1) Size?
    (2) Location?
    (3) Use?
  (f) Use?
(3) The Mouth.
  (a) Size? Large or small?
  (b) Shape?
  (c) Teeth.
    (1) Number?
    (2) Arrangement?
    (3) Position?
    (4) Use?
  (d) The Tongue.
    (1) Size?
    (2) Shape?
    (3) Relation to gills and other parts?
(4) The Gullet, a short, wide tube leading to the stomach. Thrust a probe down the throat of the fish about two inches.
  (a) Are there any teeth in the gullet?
  (b) Are there any openings to or from the gullet?
(5) The Stomach.
  (a) Position.
    (1) Is it in front or behind the gills?
    (2) Position with reference to dorsal fins?
    (3) With reference to pectoral fins?
    (4) To ventral fins?
  (b) Size?
  (c) Shape?
(6) The Cæca are small, worm-like projections at the junction of the stomach and the small intestine. They are not present in all species of fishes.
  (a) Size?

(b) Shape?
(c) Color?
(d) Number?
(e) Use?

(7) The Intestines.
(a) Are they straight or coiled?
(b) If coiled, unravel them and compare their length with that of the whole fish.

(8) The Spleen.
(a) Location?
(b) Use?

2. The Swimming Bladder—dorsal to the intestines. Use?
3. The Excretory Organs—the kidneys.
(1) Location?
(2) Use?
4. The Circulatory Organs.[1]
(1) The Heart. (Note its pericardial cavity.)
(a) Sinus venosus. Use?
(b) Auricle. Use?
(c) Ventricle. Use?
(d) Bulbous arteriosus. Use?
(2) The Arteries. Traced to what organs? Function?
(3) The Veins. Traced to what organs? Function?
(4) Use of pericardial cavity?
(5) Make a diagram showing the principal parts of the circulatory system.
5. The Nervous System.
(1) Dissect away the muscles and bones along the dorsal side, and expose the brain,[2] spinal cord, and main nerves.
(2) Special Senses.
(a) How many senses has the fish?
(b) Name them.
(c) Name those of man.

[1] See Fig. 160, "Principles of Economic Zoölogy."
[2] See Fig. 161, "Principles of Economic Zoölogy."

C. Summary

1. Skeleton (osseous or bony system).
   (1) Composition?
   (2) Use.
      (a) To the fish?
      (b) To man?
   (3) Compared with man's skeleton, what parts do you find lacking? Why lacking?
2. Muscular System.
   (1) Uses to the fish?
   (2) Uses to man?
3. The Skin.
   (1) Uses to the fish?
   (2) Uses to man?
4. The Digestive System.
   (1) Organs in man are.....
   (2) Organs in the fish are.....
5. The Circulatory System.
   (1) Organs in man?
   (2) Organs in the fish?
6. The Respiratory System. Compare with that of man.
7. The Excretory System. Compare with that of man.
8. The Nervous System. Compare with man's.
9. Special Senses. Compare with man's.
10. Why does the fish have these different systems?
11. Why is the fish more complex than the Amœba?
12. Why is the fish *aquatic*, while the bird is *aërial?*

STUDY OF CHORDATE BRANCH CHARACTERISTICS

For guidance in arriving at a correct answer, ask yourself this question, "Does this answer apply to all chordates?" If it does apply, then you have a branch characteristic.

1. The Skeleton. Of what does the endoskeleton consist?
2. The Body.
   (1) Two Body-cavities.
      (a) The upper one, or the neural cavity, contains what system?
      (b) The lower one, or the hemal cavity, contains what systems of organs?
3. The Paired Limbs. How many?
4. The Notochord. Is it present in the larval or in the adult stage, or in both? If it is not present in the adult stage, what has become of it? Its use?
5. The Gill-slits. When are they present, in the larval or in the adult stage, or in both? If they are not present in the adult stage, what has become of them? Their use?
6. The Nervous System.
   (1) Its position in the body?
   (2) Consists of what organs?
7. This animal belongs to Branch..... because it has the following characteristics of that branch. (Student name them.)

STUDY OF CHORDATE CLASS CHARACTERISTICS

1. General shape of the body of this animal?
2. Exoskeleton or External Skeleton. Scales, feathers, hair, fur, none, or what?
3. Endoskeleton or Internal Skeleton.
   (1) Occipital Condyles—one or two?
   (2) Appendages.
      (a) Called what?
      (b) Clawed or not clawed?

(c) Position on body?
(d) Number?
(e) Use?

4. Respiration, by means of.....
5. Circulation.
   (1) Single or double?
   (2) Of how many chambers does the heart consist? Name them.
   (3) Is the animal poikilothermal or homoiothermal?
6. Digestion. What digestive organs found in this animal are peculiar to its class?
7. This animal belongs to Class..... because it has the following characteristics of that class. (Student name them.)
8. Consult descriptive zoölogies for Classes.

AMPHIBIA (THE FROG)

(1) Follow suggested plan for the study of the fish, p. 112.
(2) Then compare the fish and the frog, thus: The fish is covered with scales. The frog's skin is naked. Make your comparison tell what both animals possess. Don't say the fish is covered with scales while the frog is not. You might infer that the frog was covered with feathers or fur. Make twenty comparisons.
(3) Define a frog.
(4) Compare your definitions of fish and frog. What do you find they have in common?

STUDY OF THE LIVE FROG

1. Collecting.

Wear rubbers or rubber boots, and walk along the edge of a pond or stream where you have heard the croaking of frogs.

(1) Do all of them croak?
(2) Look for small ones in the grass and weeds along the bank. Catch them by sweeping the net along over the vegetation, and carry them back to the laboratory for the tank.
(3) Observations.
  (a) What does the frog do which results in a "splash" into the water?
  (b) *How* do they strike the water?
  (c) Do they stay near the surface all the time. If not, how often do they come to the surface and for what purpose?
  (d) How do boys get a chance to shoot frogs?
  (e) When a frog floats in the water, how much of it can you see?
  (f) Color.
    (1) How does the color of its upper surface compare with that of its surroundings? Purpose of this color? From what enemies does it protect it?

(2) What color is the frog as seen by animals below it? Purpose of this color?

(g) Eggs. Look among the leaves and trash in the edge of the water for the egg masses or spawn—lumps of jelly-like material containing the eggs. Take these to the laboratory, place them in water where there is no danger of their being eaten, and watch their development.

(h) Take also large frogs, which may be captured with the hook if they cannot be gotten with the net.

2. Laboratory Study.

Place a number of frogs in a tank or tub covered with a heavy wire screen, and containing an inch or two of water.

(1) Try various kinds of food, as live insects, bits of meat, tadpoles, bread, grass, etc.
  (a) Which kind of food does the frog prefer?
  (b) How does it take its food?
  (c) Has it any special adaptation for catching insects? If so, what?

(2) Observe its methods of locomotion.
  (a) In shallow water or in no water.
  (b) In deep water.
  (c) Can a frog walk?
  (d) How far can it jump?
  (e) What adaptations has it for jumping?

(3) What is the position of a frog at rest?

(4) How does it breathe?

(5) Notice the pulsations of the "lymph hearts" on each side near the end of the backbone.

(6) What means of defense or escape has the frog?
  (a) Molest it from the front. What does it do?
  (b) Molest it from behind. What does it do?

(7) Eyes.
  (a) Are there eyelids? If so, are the upper and lower lids alike?
  (b) Observe and describe the movements of the eyelid.

(8) Voice.
  (a) Do the different species have different voices or calls?
  (b) Do they cry out in fright? In pain?

(9) Color.
  (a) Keep one frog in the light, and another in the dark for several hours, and compare their colors.
  (b) Experiment and find out if changing the color of the surroundings affects the color. If possible, repeat this experiment with a little tree toad.
(10) Wrap a wet towel about a frog and pour chloroform over it above the nostrils. Now spread the web of the foot out on a glass slide and study the circulation under the low power of the microscope.

Morphophysiologic Study

A. External Morphology

1. Size? Length in inches?
2. Shape.
  (1) Stout or slender?
  (2) Body divisions present?
3. The Head.
  (1) Size. Small, medium, large, or very large?
  (2) Shape?
  (3) Movement of lower jaw—vertical or horizontal?
  (4) The Eyes.
    (a) Position on head?
    (b) Shape?
    (c) Size?
    (d) Number of eyelids?
    (e) Color of iris?
  (5) The Ears. Back of the eyes find the tympanum.
    (a) Shape?
    (b) Size? Larger or smaller than the eyes?
    (c) Use?
    (d) Pass a needle through the tympanum into the mouth and trace the course of the *Eustachian* tube.
    (e) Why has the frog no external ear?
  (6) The Nostrils.
    (a) Where located on the head?
    (b) Are they near together or far apart?

(c) Do they open into the mouth? Probe with a bristle and see.
(d) Does the frog breathe through the nostrils, or does it swallow air, or does it do both?
(e) Are the nostrils organs of smell only, or does the frog both smell with and breathe through its nostrils?

4. The Limbs.
(1) The Anterior Limbs.
(a) Number of digits?
(b) Webbed or free?
(c) Use?
(2) The Posterior Limbs. Same questions as for anterior limbs.
(3) Compare the anterior with the posterior limbs. In what respects do they resemble each other? In what do they differ? Why?
(4) Name the three modes of locomotion of the frog. How is each performed? When? Why?

5. The Skin.
(1) Smooth or rough?
(2) Why so loose on the body?
(3) Remove the skin from the body.
(a) Is it thick or thin?
(b) Hold it up to the light. What do you observe concerning its color or color spots? Its blood-vessels?

6. The Muscles.
(1) Determine the origin, insertion, and specific use of the muscles.
(2) What do you observe concerning the muscles of the posterior limbs? What is the reason for this?

B. Internal Morphology

1. Digestive Organs. Pin the frog, on its back with the limbs fully extended, in a wax-bottomed pan or on a soft pine board. Slit open the body-cavity from the posterior end of the abdomen to the breast bone, using great care not to injure the internal organs. On each side of the posterior end of this slit make another short one at right angles to it. Now pin back

the flaps of the body walls, exposing the viscera. Insert a blow-pipe in the glottis and inflate the lungs, then tie a string tightly around the trachea to keep them inflated. Dissect under water.

(1) The Mouth.
  (a) The Teeth. Open the mouth wide. Ascertain—
    (1) The number of the teeth.
    (2) Their arrangement.
    (3) Their location.
  (b) The Tongue.
    (1) Is it long or short?
    (2) Shape?
    (3) Where attached? Why?
    (4) Is the free end entire, slightly nicked, heart shaped, or deeply notched?
    (5) How and when is the food captured?
  (c) The Glottis. Find a longitudinal slit in the back of the floor of the mouth. Into what does it open?
  (d) The Pharynx. The posterior portion of the mouth may be considered as the pharynx, which opens into the esophagus, leading to the stomach. Thrust a probe down the esophagus to the stomach.
(2) The Stomach.
  (a) Identify and describe it.
  (b) Shape?
  (c) Size?
  (d) Color?
  (e) Location?
(3) The Liver is reddish brown and lies upon the stomach.
  (a) How many lobes?
  (b) Find the gall-bladder.
    (1) Shape?
    (2) Color?
    (3) Use?
(4) The Pancreas is in the first fold of the intestine.
  (a) Shape?
  (b) Color?

(c) Size?
(d) Use?

(5) The Mesentery is a thin membrane which holds the intestines in place.
(a) Does it contain any blood-vessels?
(b) From what source do they come?
(c) To what do they lead?

(6) The Spleen is a small round red body in the mesentery.
(a) Find and identify it.
(b) Use in man?
(c) Use in the frog?

(7) The Intestines pass from the stomach to the vent.
(a) Carefully cut the mesentery and unravel the intestines. Are they coiled or straight?
(b) Are they of the same diameter, or do they vary in different portions? Where, and how much?
(c) Length as compared with that of the body?

(8) The Cloaca. This is the enlargement of the intestine just before it reaches the vent. The intestines, kidneys, and reproductive organs open into it.

(9) Sketch the alimentary canal from the mouth to the vent, properly locating and naming all its parts or organs.

2. The Respiratory Organs.
(1) The lungs. How much of the body-cavity do the lungs fill when inflated? When not inflated?
(2) The Trachea. Find the trachea and trace it to its branches, the bronchi, which lead to the lungs.
(3) Sketch the respiratory organs and name all parts.

3. The Circulatory Organs.
(1) The Pericardium, around the heart. Its use? Carefully cut through the pericardium and find the heart.
(2) The Heart.
(a) The Ventricle. The pointed posterior portion of the heart is the ventricle.
(1) Shape?
(2) Color?
(3) Size?
(4) Use?

(b) The Auricles. At the anterior and dorsal end of the heart, find the two auricles.
(1) Shape?
(2) Size?
(3) Color?
(4) Are the walls thick or thin as compared to the ventricle?
(5) Use?

(c) Conus Arteriosus. The conus arteriosus originates from the right side of the base of the ventricle, soon divides into two branches. Each divides into three, the posterior uniting in the dorsal aorta.

(d) Dorsal Aorta. Trace the principal branches.
(1) What organs or parts of the body do they supply?
(2) Notice that these arteries are firm, elastic blood-vessels.

(e) Veins. The flabby blood-vessels are veins. As you traced the arteries *from* the heart, now trace the flabby veins *to* the heart.
(1) From what organs or parts of the body do they originate?
(2) Where do they unite?
(3) Where do they empty into the heart?

(f) Sketch or make diagram of the circulatory organs, showing pericardium, ventricle, auricles, conus arteriosus, and the principal arteries and veins. Indicate upon each artery the organ supplied, and upon each vein the organ from which the vein comes.

4. Reproductive and Excretory Organs.

(1) The Reproductive Organs. If the specimen is a female, the reproductive organs will appear as long coiled tubes, filled with eggs in the breeding season. If a male, the reproductive organs will appear as a pair of yellowish bodies just below the kidneys. Do not confuse the reproductive organs with the slender branched fatty bodies which are generally present.

(2) The Excretory Organs. The kidneys are two flat bodies along the back-bone.

(a) Color?
(b) Length?
(c) Trace the ureter from each kidney to the cloaca.
(d) Sketch the kidneys, the ureters, and the openings into the cloaca.

5. The Endoskeleton. Carefully dissect off all the flesh and viscera and have the bony skeleton entire and uninjured.

(1) The Skull.
(a) Shape?
(b) Size?
(c) How many bones in the lower jaw?
(d) How many occipital condyles, one or two?

(2) The Spinal Column.
(a) Number of vertebræ?
(b) What vertebral processes are longest? Why?
(c) Why has the frog no ribs? How does it breathe without either ribs or diaphragm?
(d) Urostyle, the long bone at the posterior end of the spinal column.
(1) Shape?
(2) Is it segmented?
(3) Use?

(3) Bones of the Anterior Limbs. In man they are 1 humerus, 1 radius, 1 ulna, 8 carpals, 5 metacarpals, and 14 phalanges, or 30 bones in all. Compare the bones of the frog's anterior limb with those of man.
(a) What ones are lacking, if any?
(b) How many in the entire limb?
(c) Any peculiarity of any bone?

(4) Bones of the Posterior Limbs.
(a) Name in order the bones in man's leg.
(b) Name those in the frog's leg.
(c) How do they agree?
(d) How do they differ?
(e) How do the bones of the posterior limb differ from those of the anterior limb in this specimen? Why?

(5) The Pectoral or Shoulder Girdle.
(a) Of how many parts does it consist?
(b) Is it entirely of bone or partly of cartilage?

(c) How many bones enter into the articulation at the shoulder-joint?

(6) The Pelvic Girdle. Notice the two long bones (ilia) one on either side of the urostyle.

(a) To what is the anterior end attached?

(b) What makes the "hump" on the frog's back? Of what use is this arrangement?

(c) At the posterior end of the urostyle notice a wedge or disk-shaped body, partly bone and partly cartilage. This disk is formed by the union of the posterior extremities of the ilia and the fusing together of the two pubes and the two ischia.

(d) For what bones do they form sockets (acetabula)? Are these acetabula far apart or very close together? Why?

(e) How close are the articulations of the thigh bone to the posterior end of the body? Why?

(f) Mount this skeleton on a heavy card or a nicely planed pine board and save it for further reference in the systematic studies.

6. The Nervous System. If it is desired to work out the nervous system, chloroform the specimen, slit open the abdomen and the skin along the dorsal side, and put it into 70 per cent. alcohol, or 2 to 4 per cent. formalin for about a week, then dissect out the nervous system.

(1) Carefully remove the muscles and bones from the dorsal surface of the cranium and backbone with knife, bone-forceps, or strong forceps, bit by bit, until the brain and spinal cord are exposed, but left intact. Man's brain has three coverings: dura mater, pia mater, and arachnoid. Can you identify these coverings on the frog's brain and spinal cord?

(2) The Brain.[1]

(a) The Cerebrum. Identify it with its two hemispheres between the eyes.

(1) Shape?

(2) Size?

(3) Is it convoluted or smooth?

(4) Function?

[1] See Fig. 185, "Principles of Economic Zoölogy."

(b) The Optic Lobes lie just posterior to the cerebrum.
  (1) Shape?
  (2) Size?
  (3) Function?
(c) The Cerebellum is posterior to the optic lobes.
  (1) Shape?
  (2) Size?
  (3) Is it convoluted, smooth, or ridged?
  (4) Use?
(d) The Medulla Oblongata lies posterior to the cerebellum. It is widest anteriorly and gradually merges into the spinal cord.
(e) For ventral view of the brain consult some good figure and identify the cerebral nerves. In a man there are twelve pairs. How many pairs in the frog? Name the pairs of cranial nerves in man and state their destination and use. Same for those of the frog.

(3) The Spinal Cord.
  (a) Shape?
  (b) Length?
(4) The Spinal Nerves. Place the frog ventral side up and carefully remove the viscera. In man there are thirty-one pairs of spinal nerves. How many can you identify coming from the spinal cord in the frog?
  (a) Are all these nerves of the same size when they leave the cord?
  (b) With what does the second pair (counting from the anterior end of the cord) unite?
    (1) What does this union then form?
    (2) What muscles does it supply?
  (c) What four other spinal nerves unite?
    (1) Do they subdivide?
    (2) Trace them down to their union in one large nerve, the sciatic. What muscles does it supply?
(5) The Sympathetic Nerves. A small knotted nerve cord may be found along the side of the dorsal aorta.
  (a) Trace each nerve.
  (b) How many knots or ganglia do you find?
  (c) Use of the sympathetic nervous system?

REPTILIA (THE TURTLE)

(1) Follow plan of study for the fish, p. 112.

(2) Compare the turtle and the frog.

(3) How do you account for the turtle's carapace and plastron?

(4) How do you account for the absence of limbs in the snake? Did they ever have limbs? Were snakes larger formerly than now? See your Geology on reptiles.

(5) How do you account for the classification of snakes, turtles, alligators, and crocodiles as Reptilia?

STUDY OF THE LIVE TURTLE

1. Field Study.

Protected by rubbers or rubber boots, go *very cautiously* along the banks of a secluded pond or stream.

(1) Look upon fallen tree trunks or stumps for turtles basking in the sunshine.
   (a) What do they do if they become aware of your presence?
   (b) *How* do they become aware of it?
   (c) *How* do they get back into the water?
   (d) Wait *quietly* to see if they will return.

(2) Fish for turtles with a hook and stout line. For bait use a short piece of fresh meat.

(3) When one is caught, put it in the mud outside of the stream and watch it.
   (a) If it walks away, does it carry its body above the ground or does it creep along with its body dragging on the ground?
   (b) What does it do with the head and neck when walking?

(c) Follow it very cautiously, not losing sight of it until it stops.
(d) *How* does it conceal itself in the mud?
(e) Is its color of use to it in its natural environment? If so, of what use?

2. Laboratory Study.

Place the turtle in the tank with about an inch of water.

(1) Watch it, to see how it breathes.
(2) Experiment with various kinds of foods, leaving them overnight in the tank. What kind or kinds does the turtle eat?
(3) Leave it several days without food. Then offer it fresh meat.
  (a) How does it take its food?
  (b) Does it chew its food? Does it swallow it whole?
  (c) Of what use is its beak?
(4) Neck.
  (a) Why is the neck so long?
  (b) Turn it over on its back. *How* does it turn over?
(5) Locomotion.
  (a) Put the turtle on the ground or floor. Does it lift or drag the body when walking?
  (b) Put it in deep water.
    (1) Watch it swim. Describe.
    (2) What adaptations has it for swimming?
    (3) Can it dive?
(6) Protection.
  (a) Can it withdraw its head and limbs into the shell?
  (b) What does it do with its tail?
  (c) Compare with a box-turtle, if you can get one.
(7) Has it any means of defense aside from its shell? If so, what?
(8) Eyelids.
  (a) How many?
  (b) Movements?
(9) Voice.
  (a) Does it make any sound? If so, how?
  (b) For what purpose?

Morphophysiologic Study

A. External Morphology

1. Size. With the animal lying on its back and extended, what is the length from the tip of its nose to the end of its tail?
2. Shape of the Body.
   (1) Stout or slender?
   (2) Body divisions present?
3. The Head.
   (1) Size. Small, medium, large, or very large?
   (2) Shape?
   (3) Measurements.
      (a) Length?
      (b) Width?
      (c) Depth?
   (4) Lower Jaw Movement. Vertical or horizontal?
   (5) Color?
   (6) Eyes.
      (a) Position on head?
      (b) Shape?
      (c) Number of eyelids?
      (d) Color of iris?
   (7) Ears.
      (a) Can the turtle hear?
      (b) Is there any external evidence of ears?
      (c) Why is this so?
   (8) Nostrils.
      (a) Where are they located on the head?
      (b) Are they near together or far apart?
4. The Neck.
   (1) Shape?
   (2) Length?
   (3) Color?
   (4) Peculiarity?
5. The Limbs.
   (1) The Anterior Limbs.
      (a) Number of digits?
      (b) Are they webbed or free?
      (c) Use?

(2) The Posterior Limbs.
(a) Number of digits?
(b) Are they webbed or free?
(c) Use?
(3) Compare the anterior with the posterior limbs.
(a) In what respects are they alike?
(b) In what respects do they differ?
(c) Give reasons for these resemblances and differences.

6. The Skin.
(1) Smooth or rough?
(2) Thick or thin?
(3) Where thickest? Where thinnest? Why?
(4) Loose, like the frog's skin, or tight?
(5) Color?

7. The Shell. The upper portion is the carapace, the lower portion is the plastron.
(1) The Carapace.
(a) Sketch it—one-half natural size.
(b) How many marginal epidermal plates? Letter each of these in your sketch (a).
(c) How many dorsal plates? Letter each (b).
(d) How many costal plates (between marginal and dorsal)? Letter (c).
(e) Now write a brief description of these epidermal plates, stating the total number, and the shape, size, color, use, and arrangement of the different kinds.
(2) The Plastron.
(a) Sketch it.
(b) Of how many epidermal plates is it composed?
(c) What is their size, shape, color, and arrangement?
(d) Compare plastron with carapace as to shape, size, and relation to other parts.

B. Internal Morphology

1. Preliminary Work.
(1) Killing the turtle. Take a firm hold of its head and open its mouth. Insert a blow-pipe into the glottis

at the base of the tongue. Put about a tablespoonful of chloroform into the blowpipe and blow it into the lungs. Now tie a string tightly around the neck to keep the air out of the trachea, and let the turtle lie fifteen or twenty minutes. Another method of killing preferred by some is simply to place the turtle on its back in the "killing box." Wrap a cloth well saturated with chloroform about its head. Close the lid tightly and allow the turtle to remain about twenty minutes, then tie a string very tightly around its neck.

(2) Slit open the skin of the ventral side of the neck and expose the trachea, esophagus, and the strong muscles of the neck.

(3) Remove the plastron by cutting through the skin along its margin and sawing or cutting through the plastron where it joins the carapace. With a sharp scalpel dissect away the muscles from the inner surface of the plastron, cutting very close to it, so as to leave the internal organs uninjured and in place.

(4) Cut away the pericardium, the semitransparent membrane covering the heart, taking care not to cut the blood-vessels. Observe the beating of the heart. What is the order of contraction—auricles and ventricle—or the reverse?

(5) With a sharp scalpel cut the peritoneum along the middle line, beginning just posterior to the heart and continuing posteriorly. In doing this, place the point of the scalpel edge up under the membrane and cut outward, *taking great care not to injure any underlying organs.*

(6) Cut the string about the neck. Insert a blowpipe in the glottis and inflate the lungs, and *quickly* tie a string tightly around the trachea to keep them inflated. Now you are ready to begin the study of the internal organs.

(7) First note their position in the body-cavity.

(a) Where is the heart situated with reference to the digestive organs?

(b) What is the position of the lungs with reference to the heart and stomach?
(c) Note the position of the large liver and make a study of it in its place.
(1) Color?
(2) Location?
(3) Number of lobes?
(4) Use?
(5) Identify and locate the gall-bladder? Use?
(6) Trace the bile-ducts to the duodenum or anterior loop of the intestine.

2. The Circulatory System.
(1) The Heart.
(a) Size?
(b) Shape?
(c) Parts present?
(d) Pericardium. Use?
(e) Ventricle. The pointed posterior portion of the heart is the ventricle.
(1) Shape?
(2) Color?
(3) Size?
(4) Use?
(f) The Auricles. At the anterior and dorsal end of the heart find the two auricles.
(1) Are their walls thick or thin as compared with those of the ventricle?
(2) Shape?
(3) Size?
(4) Color?
(5) Use?
(2) Arteries.
(a) Trace the two aortæ from the heart to their union.
(b) Trace arteries to the stomach and to other principal organs.
(3) The Veins. The flabby blood-vessels are veins. As you traced the arteries *from* the heart, now trace the veins *to* the heart.

(a) From what organs or parts of the body do they originate?
(b) Where do they unite?
(c) Where do they empty into the heart?

(4) Make a diagram of the circulatory organs, showing the pericardium, ventricles, auricles, and principal arteries and veins. Indicate upon each artery the organ supplied, and upon each vein the organ from which it comes.

3. The Digestive System.

(1) The Mouth.
(a) Shape?
(b) Size?
(c) Position, terminal or ventral?
(d) How wide does the mouth of your specimen open?
(1) How does it open so wide?
(2) When?
(3) Why?

(2) The Teeth.
What does the turtle have instead of teeth? Why?

(3) The Tongue.
(a) Is it long or short?
(b) Shape?
(c) Where attached?
(d) Rough or smooth?
(e) Use?

(4) The Mandibles, or Jaws.
(a) Size and strength?
(b) Are the edges smooth or serrated?
(c) Do they overlap, or do they close against each other? Why?
(d) Use of the mandibles?

(5) The Esophagus or Gullet.
(a) Is it flabby and collapsed, or a rigid and open tube like the trachea?
(b) Of what kind of tissue is it composed?
(c) Thrust a probe down the gullet and ascertain its diameter.
(d) Ascertain its length to the stomach. Why so long?

(6) The Stomach. Locate and describe, giving its shape, size, and color.
(7) The Liver has been studied. (See (7) (c), p. 162.)
(8) The Pancreas is in the first fold of the intestine.
(a) Shape?
(b) Color?
(c) Size?
(d) Use?
(9) The Mesentery is a thin membrane which suspends the intestines.
(a) Does it contain any blood-vessels?
(b) From what source do they come?
(c) To what do they lead?
(10) The Spleen is a small dark red body in the mesentery.
(a) Locate it.
(b) Use?
(11) The Intestines pass from the stomach to the vent.
(a) Carefully cut the mesentery and unravel them. Are they coiled or straight?
(b) Do they vary in diameter in different places? If so, where, and how much?
(c) Length of turtle's intestines as compared with the length of its body?
(12) The Cloaca. This is the enlargement of the intestine just before it reaches the vent. The intestines, kidneys, and reproductive organs open into it.
(13) Sketch the entire alimentary canal from the mouth to the vent, placing the various organs in their proper order and naming each of them.

4. The Respiratory System.
(1) The Nostrils.
(a) Do they open into the mouth? Probe with a bristle and see.
(b) Does the turtle breathe through its nostrils only, or does it swallow air also?
(c) Does the turtle both breathe through and smell with its nostrils?
(2) The Glottis. Find an opening in the base of the tongue leading to the trachea.

(3) The Trachea. Trace it to its branches, the bronchi, which lead to the lungs.
(a) Is it long or short? Why?
(b) Is it an open rigid tube or a flabby collapsed one? Why?
(c) Of what kind or kinds of tissue is it composed?
(4) The Lungs.
(a) How much of the body-cavity do they fill when inflated?
(b) Estimate approximately their capacity in cubic inches.
(5) Make a diagram of the respiratory organs and name each.

5. The Reproductive and Excretory Systems.
(1) The Reproductive Organs.
(a) If the specimen is a female, the reproductive organs will appear as long coiled tubes filled with eggs in the breeding season.
(b) If a male, the reproductive organs will appear as a pair of yellowish bodies just below the kidneys. Do not confuse the reproductive organs with the slender branched fatty bodies generally present.
(2) The Kidneys are two flat bodies along the backbone.
(a) Color?
(b) Length?
(c) Trace the ureter from each kidney to the cloaca.
(d) Sketch the kidneys, ureters, and openings into the cloaca.

6. The Nervous System. Follow the directions given for the nervous system of the frog.

How do the parts of the turtle's brain compare with the frog's as to size, shape, and appearance?

7. The Muscular System.
(1) Find the origin and insertion of the muscles that protract and retract the neck. What wonderful adaptations for a specific purpose do you discover?
(2) Dissect off all the muscles from the bones, leaving enough ligaments to hold the bones in their proper places.

8. The Skeleton, or Osseous System.
   (1) The Head. Sketch it, naming the principal bones in it.
   (2) The Neck.
      (a) Number of vertebræ?
      (b) Shape of each?
      (c) Use?
   (3) The Pectoral Girdle. Sketch the girdle, locating and naming the coracoid, precoracoid, scapula, and a ligament connecting the distal portions of the coracoid and the precoracoid. This ligament represents the epicoracoid of some reptiles.
   (4) The Front Limb.
      (a) Sketch, showing humerus, radius, ulna, the carpal and metacarpal bones, the phalanges, and the claws.
      (b) Why is the front limb so stout and paddle-like?
   (5) The Vertebral Column, from head to tail.
      (a) Of what does it consist?
      (b) Number of vertebræ?
      (c) Its special modifications?
   (6) The Pelvic Girdle. Sketch the girdle, locating and naming the ilium, ischium, and the pubes.
   (7) The Hind Limb.
      (a) Sketch, locating and naming all the bones of the leg and foot, from the femur to the claws.
      (b) Use of web?
      (c) Use of long claws?
      (d) Compare the hind limb with the front limb as to shape, size, length, and use.
   (8) The Tail.
      (a) Number of vertebræ in the turtle's tail?
      (b) Use to the turtle?
      (c) Its peculiarity?
   (9) Remove the epidermal plates from one half of the shell.
      (a) Sketch the bony plates from the dorsal side of the carapace.
      (b) Sketch the bony plates from the ventral side of the carapace.
      (c) How many do you find?

(d) How many ribs?
(e) How many ribs and bony plates united? Why?
(f) How do the bony plates compare with the epidermal plates in size, shape, number, and arrangement?
(g) Of what does the carapace consist?
(h) Use of this complicated structure?
(i) The Plastron.
  (1) Sketch it.
  (2) How many epidermal plates? Color?
  (3) How many bony plates?
  (4) Compare the plastron with the carapace as to shape, size, and relation to other parts.

AVES (THE BIRD)

Follow the plan for Pisces, p. 112.

Compare birds and reptiles.

How do you account for the presence of feathers on the bird?

For the bird's ancestors, see your geology, Archæopteryx.

See Chapman's "Bird Life" for a plan for spring or fall study of birds.

STUDY OF LIVE BIRDS

A. General Study

1. Winter Birds.
   (1) Make a list of all the birds which remain in your locality through the winter.
   (2) Are they more warmly clad than the birds which go south in winter?
   (3) Why do they not migrate?
   (4) What is their food? Can they get a comfortable supply in winter?
2. Migration.
   (1) What birds are the first to migrate?
   (2) What ones are the last to go?
   (3) What ones are the first to come back in the spring? *Don't guess. Keep a record,* giving the date for the first time you see each bird as it returns in the spring. Make several trips to the woods and streams to increase the list.
   (4) Which birds are gregarious?
   (5) Which come in pairs?
   (6) Can you give any evidence from your own observation of any birds returning to the same place to nest from year to year?
3. Movements on the Ground.
   (1) Make a list of the birds that hop.
   (2) Make a list of those that walk.

4. Voice.
   (1) Make a list of those that sing.
   (2) Do you notice different calls or tones by the same bird?
      (a) Are they for different purposes?
      (b) What emotions or information do birds express by voice?
   (3) Give some of the names applied to the calls of various birds.
5. Nesting Habits.
   (1) Make a list of birds which build their nests upon the ground.
   (2) Of those that build in trees.
   (3) What general truth do you observe concerning the colors of birds which stay most of the time on the ground? Is this true of their color ventrally?

B. Special Study

Select one or two birds which you have an opportunity to watch closely, and report upon the following points:

1. Nesting Habits.
   (1) Which builds the nest, the male or the female? Or do both?
   (2) Does the male feed his mate or does he watch the nest while she gets her food?
2. Food.
   (1) What is their food?
   (2) Which feeds the young? What does it feed them?
   (3) Judging from this food, are they of use or harm to the farmer and fruit-grower?
   (4) When (what time of day or night) do they feed?
   (5) How do they secure their food?
   (6) What adaptations for securing food have they?
   (7) Name some adaptations for securing food which you have noticed in other birds.
   (8) Does this bird ever store its food? If so, how and where? If not, do you know of any bird which does?
   (9) How does this bird drink? Do all birds drink that way? (Watch the pigeon drink.)

3. The Young.
   (1) How does this pair of birds defend its young?
   (2) Is there any recognition of the parent by the young? If so, by what means?

Morphophysiologic Study

Note.—If the teacher can supply the feathers, it will be well to take the study of a "contour" feather, and a "down" feather, before killing the bird. A common pigeon makes an excellent study, but an English sparrow may be used.

Kill the bird by chloroforming it in the "killing can" for ten minutes. Then slit the skin of the neck and tie a string tightly around the trachea close to the head.

One bird will be needed for the study of muscles, viscera, and nervous system, and another for the skeleton. If it is desired to mount the skeleton and material is scarce, two students may work together after the internal morphology is reached, so that all the material needed will be one bird for each student.

If the student does not get ready the first day for the internal morphology, insert a blowpipe in the bird's trachea and inflate the lungs (see B, 1 and 2), or they may become fixed so that they cannot be inflated.

Place specimen in "preserving fluid" after class each day.

A. External Morphology

1. Size.
   (1) What is the length from the tip of the bill to the end of the tail?
   (2) Weight of the bird with the feathers on?
2. Shape of its body? Why such a shape?
3. Body Divisions. Head, neck, body, tail. Length of each?
4. The Head.
   (1) Size. Small, medium, or large, compared with the body?
   (2) Shape? Why such a shape?
   (3) Covering of the head.
      (a) Parts feathered?
      (b) Parts naked?

(4) Range of motion of the head?
(5) Eyes.
(a) Shape?
(b) Size?
(c) Position on the head? Why so placed?
(d) Eyelids. Are there two or three to each eye? Raise the upper lid and look in the interior angle for the nictitating membrane. How does a bird wink?
(6) Ears.
(a) Shape?
(b) Size?
(c) Position on the head?
(d) How protected?
(7) Beak.
(a) Length in inches?
(b) Size?
(c) Color?
(d) Use?
(e) Lips. Has the bird any lips? Why is this true?
(8) Nostrils.
(a) Number?
(b) Position on the beak?
(c) Openings. With a probe find out where the nostrils open into the mouth.
(9) Mouth.
(a) Tongue. Open the bird's mouth and examine the tongue. Describe it.
(b) Glottis. Back of the tongue, find the glottis. What is its shape? What is its character?
(c) Eustachian tubes. Pass a bristle through the tympanum or ear-drum and see where it enters the mouth. Is there one or two openings into the roof of the mouth?

5. The Neck.
(1) Length?
(2) Covering?

6. The Exoskeleton. The feathers, claws, and scales form the exoskeleton.

(1) The Feathers.
  (a) Identify (1) the *contour* feathers, (2) the down feathers, (3) the pin-feathers, or undeveloped feathers, and (4) the filoplumes, or hair-like feathers that remain on the bird after plucking.
  (b) Parts of the body covered with feathers?
  (c) Parts of the body not covered with feathers? Why?
  (d) Color, or color patterns, and how made? Are they bilaterally symmetric?
  (e) A Contour Feather.
    (1) Identify the quill (calamus), the shaft (rachis), and the vane, which is made up of barbs, barbules, and barbicels.
    (2) Sketch a contour feather, showing and naming all the parts.
  (f) A Down Feather. Compare with a contour feather and state parts lacking, if any.
  (g) A Filoplume. Compare with a contour feather.
  (h) Use of each kind of feathers to the bird?
  (i) Tail Feathers.
    (1) How many long quill feathers on the tail?
    (2) Shape of the tail when feathers are spread out? Shape when closed?
    (3) Symmetry of the vane? How do these feathers overlap? Why?
    (4) Color or color patterns when open? When closed? Why?
    (5) Number, color, and arrangement of the upper tail coverts? Of the lower tail coverts?
  (j) Wing Feathers.
    (1) Primaries on the pinion. Usually nine or ten. How many do you find?
    (2) Tertiaries on the upper arm. How many?
    (3) How many in all? How many upper coverts? Lower coverts?
  (k) Body Feathers.
    (1) Any contour feathers? If so, how many?
    (2) Any down feathers? Approximate number?

(3) Any filoplumes?
(4) How are the body feathers arranged?
(l) Of what use are feathers to the bird? To man?
(m) Pluck off the feathers.
(1) Where is the skin thin? Where thick?
(2) Can you find *apteria*, or spaces which did not bear feathers?
(3) What difference is there in the size of the bird before picking and after picking?
(4) Weigh the plucked bird. Compare this weight with that first found. What is the difference between these weights, or the weight of the feathers?
(2) Scales. Do the scales overlap? Are the anterior and posterior scales alike?
(3) Claws.
(a) How do they unite with the toes?
(b) How do they compare in color and texture with the covering of the toes and legs?
(c) Use of the claws? Are they sharp and strong enough to be successful weapons of defense?

7. The Muscles. Skin the bird and expose the muscles. Hold the skin up to the light. Do you see any blood-vessels? What is their arrangement? Their use? Demonstrate (separate out) the following muscles:

(1) Those that move the wing as a whole.
(2) Those that move the parts of the wing upon each other.
(3) Those that move the neck.
(4) Those that move the leg on the body. Bend the leg close up to the body and note the effect upon the toes. What difference is there in the position of the toes when the leg is straight from their position when the bird is on its perch?
(5) Those that move the parts of the leg on each other.
(6) Those that move all the toes at once.
(7) Those that move each toe independently.
(8) Remove the muscles from the sternum, noting the blood-vessels and nerves which enter them near the shoulders.

B. Internal Morphology

1. Carefully lift the abdominal wall, and, with the scissors, slit it from the posterior edge of the sternum to the anus. Now, make a transverse slit on each side along the posterior edge of the sternum and cut away the flaps of the abdominal wall.

2. Now make a tiny opening in the trachea below the string you tied about it, insert the blowpipe, and inflate the lungs and air sacs.

Note (1) the paired abdominal sacs near the dorsal wall anteriorly, but the ventral wall posteriorly, (2) the axillary sacs under the wings, and (3) the branched interclavicular sac beneath the anterior end of the sternum and the wish-bone, or clavicles.

(4) Do you find other air sacs?
(5) What part of the lung expands first in inflating?
(6) Do you notice any movement of the appendages when you inflate the pigeon's lungs?
(7) Explain how air blown into the lungs affects the bones.
(8) Tie the trachea below the entrance of the blowpipe and keep the lungs inflated if you can.

3. Next, disjoint the coracoid bones from the scapulæ, or shoulder-blades, and cut the ribs loose from the sternum. Remove the coracoids, clavicles, and the sternum, thus exposing the internal organs. Note the compactness with which the internal organs are placed. Why?

4. The Liver.
   (1) Color?
   (2) Location?
   (3) Number of lobes?
   (4) Use?
   (5) Identify and locate the gall-bladder. Use?
   (6) Trace the bile-ducts to the duodenum, or anterior loop of the intestine.

5. The Circulatory System.
   (1) The Heart. Locate and identify the heart with its pericardium.
      (a) Carefully remove the pericardium.

(b) Identify and describe the two auricles and the two ventricles.

(c) Snip off the apex of the heart with a pair of scissors and observe the cavities of the two ventricles. Note the difference (1) in shape, and (2) in thickness of walls. Explain.

6. The Digestive System.

(1) Mouth.

(a) Size?

(b) Shape?

(c) Beaks for teeth. Why?

(2) The Pharynx opens into the gullet.

(3) The Gullet.

(a) Is the gullet, or esophagus, the same size all the way to the gizzard? Can the pigeon swallow with its head down?

(b) What is the first enlargement called? Of what use is the crop?

(c) The glandular stomach is the slight enlargement near the gizzard. What is its size compared with that of the crop? If the opening into the gizzard were closed, could fluids pass from the glandular stomach into the intestine?

(4) The Gizzard.

(a) Of what use is the gizzard, or muscular stomach?

(b) Make a cross-section through the gizzard.

(c) Of what does it consist?

(d) Character of the lining?

(e) What does it contain?

(f) How many openings has the gizzard, and into what?

(g) Can the opening from the glandular stomach be closed?

(h) Is the gizzard cecal?

(5) The Duodenum. The first loop of the intestine is called the duodenum.

(a) How and by what is it held in position?

(b) From what is the intestine suspended?

(c) Note the veins and arteries in the mesentery.

(6) The Pancreas, a yellowish, slender, glandular organ, lies within the loop of the duodenum. Find the pancreatic ducts leading to the right limb of the loop of the duodenum.

(7) The Spleen, a small, flat, red body, lies to the right of the glandular stomach. Do you find any duct leading from the spleen?

(8) The Intestine continues from the duodenum, its anterior part, to the cloaca, the enlargement at its posterior end.

(a) Is it coiled, looped, or straight?

(b) Is it the same size all the way?

(9) The Rectal Ceca are two lateral sacs or branches of the intestine at the end of the small intestine.

How long are they and how do they end? Use?

(10) The Rectum, or large, straight intestine, leads from the entrance of the ceca to the cloaca.

How long is the rectum?

(11) The Liver. (See B, 4.)

(12) Sketch the Alimentary Canal, name all its parts in order, and state the use of each part in the work of digestion.

7. The Respiratory System.

(1) The Glottis. Look at the base of the tongue for the opening into the trachea.

(a) Does the food pass over it in entering the esophagus?

(b) If so, how is it prevented from passing into the windpipe?

(2) The Trachea. Trace the trachea down to its divisions.

(a) Is it the same size all the way?

(b) The enlargement at its anterior end is the larynx and the one at its posterior end is the *syrinx*, or voice-box.

(3) The Bronchi are the branches, or divisions, of the trachea.

Do they differ in size?

(4) Remove the alimentary canal and sketch the respiratory organs.

8. The Excretory Organs. Find two dark-colored organs, the kidneys, close along the back.

Trace a ureter from each to the cloaca.

9. The Reproductive Organs, paired in the male and single in the female, also open by ducts into the cloaca.

10. The Nervous System.

(1) The Brain.

(a) Carefully cut away the upper part of the skull and expose the brain.

(b) Is it smooth or convoluted?

(c) Identify and describe the cerebrum, cerebellum, the two olfactory lobes in front of and below the cerebrum, anterior to and below the cerebellum.

(2) The Spinal Cord.

(a) Remove the bone along the cervical vertebræ and expose the spinal cord until the *brachial plexus* is reached.

(b) Trace nerves to the wings.

(c) Continue to expose the spinal cord until the *lumbar plexus* is reached.

(d) Trace the nerves from the lumbar plexus to the thigh.

(e) Continue exposing the spinal cord till the *sacral plexus* is reached.

(f) Trace the sciatic nerves to the legs.

(g) If possible, continue exposing the spinal cord until the *plexus pudendus*, which supplies the tail, is reached.

(3) Sketch the brain and spinal cord, showing the principal plexuses. State the use of each part of the brain. Tell what part of the body is supplied with nerves from each plexus.

C. The Endoskeleton[1]

Clean away the flesh from the bones of the unmutilated bird, leaving all parts articulated.

Weigh. What per cent. of the bird is bone? Why are the bones so light?

[1] See Fig. 216, "Principles of Economic Zoölogy."

1. The Skull.
   (1) Note the quadrate bone, to which the lower jaw is attached.
   (2) Note the large posterior opening, the *occipital foramen*, in the base of the skull.
   (3) Are there one or two little knob-like projections (*occipital condyles*) which fit into the atlas, or first cervical vertebra?
   (4) Are the bones of the skull compact and heavy, or spongy and light?
   (5) Are the bones completely ankylosed together, or can you distinguish the sutures between them? The sutures are less plainly visible in an old bird than in a young one.
2. The Vertebræ.
   (1) Notice how the first and second vertebræ fit together.
   (2) How many vertebræ are there between the skull and the first pair of ribs articulating with the sternum?
   (3) How many vertebræ bear ribs?
   (4) The Sacrum. Fourteen or fifteen vertebræ are fused together to form the sacrum which supports the pelvic girdle. Note the openings through which the spinal nerves pass.
   (5) How many free caudal vertebræ do you find?
   (6) Note the terminal bone, the pygostyle, formed from the fusing together of several vertebræ.
3. The Ribs.
   (1) How many ribs do not articulate with the sternum?
   (2) How many ribs articulate with the sternum?
      (a) In what direction does the vertebral, or dorsal, portion of these ribs extend?
      (b) In what direction does the ventral or sternal portion extend?
      (c) How do they meet? At an angle or in a straight line?
      (d) What is the advantage of this arrangement?
4. The Pectoral, or Shoulder Girdle.
   (1) On each side, it consists of a scapula, or shoulder-blade, a stout coracoid bone reaching from the scapula to the sternum, or breast-bone, and the slender clavicle.

(2) The two clavicles are ankylosed together at their ventral ends, forming the "wish-bone."
(3) How is this end joined to the keel of the sternum?
(4) To what do the proximal ends articulate?

5. The Sternum, or Breast-bone, is the somewhat triangular bone below the body-cavity.
(1) What is its shape next to the viscera? Why?
(2) What is the purpose of the keel which projects on its ventral side?
(3) What bones are attached to the sternum?

6. The Wings.
(1) Compare the bones of the wing with those of the arm of man.
(2) Name and describe the bones of the proximal and distal portions.
(3) In what direction from its proximal attachment does each of these portions of the wing extend?
(4) The distal portion of the wing is made up of the bones of the carpus, metacarpus, and phalanges, which are much modified, fused, degenerate, or lacking.
(5) Compare your specimen with some good figure of it and find two free carpal bones, the radial and the ulnar, the carpometacarpus, a long curved bone formed by the fusion of the distal carpal bones with the first three metacarpals, and the first three digits, the third consisting of but a single bone.

7. The Pelvic Girdle consists of a right and left innominate bone, each of which is formed by the fusion of the *ilium*, *ischium*, and *pubis*, at the union of which is the *acetabulum*, or depression for the head of the femur. See if you can distinguish these bones.

8. The Legs.
(1) The femur, or thigh bone, fits into the acetabulum at its upper end.
(a) What is its length?
(b) In what direction does it extend from its upper attachment?
(2) The middle portion of the leg is composed of two bones; the tibiotarsus or long bone, formed by the fusion

of the tibia with the proximal tarsal bones, and the fibula, a tiny, slender bone sometimes fused with the large bone.

(3) The distal portion consists of the bones of the foot.

(a) The shaft, or tarsometatarsus, is formed by the fusion of the distal tarsal bones and the second, third, and fourth metatarsals. What direction, then, does the sole of the foot take?

(b) The toes.

(1) Upon what does the pigeon walk?

(2) How many toes are present?

(3) In what direction do they extend?

(c) Make a sketch of the right leg, showing all the bones in their natural positions when the bird is standing. Name each.

MAMMALIA (THE RABBIT)

Follow plan suggested for the study of the fish, p. 112.

Compare the fish, frog, turtle, bird (used), and rabbit (or mammal used). Make ten comparisons.

What branch (chordate) structures do you find they have in common?

Library report on domesticated mammals, from reading list assigned by teacher.

Compare your definitions of a fish, a frog, a turtle, a bird, and a mammal.

STUDY OF A LIVE RABBIT

Study the rabbit in the field if possible. If not, cage a wild rabbit and study it in the laboratory, or visit some one's pet rabbit.

If none of these are available, then study any live mammal, as the cat, guinea-pig, white rat, squirrel, prairie-dog, or even a horse or cow, making your own outline.

Field Study.

Go at morning, noon, and evening, cautiously and repeatedly, along the hedges or neglected roadsides in the spring, and look for rabbits.

(1) At what time of day do you find one at home? At what time of day do you find one feeding?
(2) What does the rabbit do when it becomes aware of your presence?
(3) What seems to be its first impulse for protection?
(4) What are its adaptations for concealment?
(5) In what position are its ears when it is squatting?
(6) Does it change the direction of its ears when listening? Whistle to it while you watch.
(7) Does it see or hear you first?
(8) Can it see in all directions without turning its head?
(9) Does it sleep in the daytime?

(10) Do rabbits play together? When?
(11) What are its modes of locomotion?
(12) How far can it jump?
(13) How high can it jump?
(14) Can it swim?
(15) When chased by dogs, why does it "circle" on its tracks?
(16) Did you ever hear a rabbit make a cry or sound? When? Why?
(17) What is a rabbit's food?
(18) What harm do they do?
(19) In what kind of nests do they rear their young? When?
(20) Are the young rabbits helpless, naked, and blind, or covered with hair, active, and can see?

Morphophysiologic Study

A. External Morphology

1. Size.
   (a) Length in inches? (From tip of nose to tip of last vertebra of tail.)
   (b) Stout or slender in body? Diameter from side to side? Dorsoventrally?
2. Shape of Body?
3. Head.
   (1) Size. Small, medium, or large?
   (2) Cause of such a shape?
   (3) Eyes.
      (a) Shape?
      (b) Size?
      (c) Position on head?
      (d) Number of eyelids?
   (4) Ears.
      (a) Shape?
      (b) Size? Length in inches? Why so large?
      (c) Position on head?
   (5) Upper Lip.
      (a) Shape? Why such shape?
      (b) Use?

(6) Lower Lip.
(a) Shape?
(b) Use?
(7) The Tongue?
(a) Shape?
(b) Size?
(c) Surface?
(d) Use?
(8) The Teeth.
(a) Incisors.
(1) Number of incisors in each jaw?
(2) What is their particular shape? Why? Are they *just alike* in the upper and lower jaw?
(3) What portion of these teeth is covered with enamel? Why is not their whole surface covered?
(4) Upon what do the lower incisors fit against when the mouth is closed?
(5) Why the space back of the incisors?
(6) What teeth are lacking?
(7) How does the rabbit obtain its food?
(8) How does the rabbit chew its food?
(9) Is the movement of the lower jaw vertical, or horizontal, or both? Feed one and watch the jaws move.
(b) Premolars.
(1) Shape?
(2) Number in each jaw?
(3) Use?
(c) Total number of teeth?
(9) Cheeks. Hairy or smooth inside? Why?
(10) Vibrissæ or "Whiskers."
(a) Where situated?
(b) Number on a side?
(c) Color?
(d) Use?
4. The Neck.
(1) Shape?
(2) Length?
(a) Length compared with head?
(b) Compared with body?

5. The Tail.
   (1) Shape?
   (2) Length?
   (3) Why so short?
   (4) Color?
      (a) Dorsally?
      (b) Ventrally?
      (c) Why this difference in color?
6. The Limbs.
   (1) The Anterior Limbs.
      (a) Length?
      (b) Number of digits?
      (c) Length of each digit?
      (d) How many are clawed? Why clawed?
      (e) Are the feet padded with hair or naked? Why?
   (2) The Posterior Limbs.
      (a, b, c, d, e) Same questions as for anterior limbs.
      (f) How much longer are they than the anterior limbs? Why so much longer?
   (3) Locomotion.
      (a) Is the rabbit digitigrade or plantigrade? Which are you?
      (b) Indicate the way a rabbit makes tracks when running.
      (c) How great a distance, in feet, will the rabbit jump when running? How many feet high will it jump?
      (d) Did you ever see a rabbit walk? Swim? Climb?
7. The Skin. Remove the skin from the limbs. About the quickest way is to make a slit in the skin around the center of the body and to have two persons pull the skin both ways at once.
   (1) Is the skin thick or thin?
   (2) Use to the animal? To man?
8. The Muscles or lean meat.
   (1) Determine the origin, insertion, and use of ten muscles. Consult human physiology. Use of so much muscle?
   (2) Demonstrate the workings of the muscles in the posterior foot.

B. Internal Morphology

In your dissections, be careful not to injure the sternum, ribs, or any other bones, as you will need them in your study of the skeleton.

Cut through the abdominal muscles along the median line from the pelvis to the sternum. From the middle of this slit, make a short one on each side at right angles to it, and turn back the muscular flaps, exposing the internal organs.

How do the abdominal muscles compare in thickness with those on other parts of the body? Why?

Before proceding with the dissection, or putting the specimen into formaldehyd, insert the blowpipe in the trachea, inflate the lungs, and tie a string tightly about the trachea below the blowpipe.

1. Peritoneum, or lining of the body cavity. Its surface and appearance?
2. The Diaphragm. A muscular partition divides the body into two portions, the anterior, containing the heart and lungs, and the posterior, containing the abdominal viscera.
3. Note the position of the organs in the body cavity?
4. The Circulatory System.
   - (1) The Pericardium.
     - (a) Identify and describe it.
     - (b) Use?
     - (c) Contents?
   - (2) The Heart.
     - (a) Shape?
     - (b) Size?
     - (c) Use?
     - (d) Number of auricles?
       - (1) Position?
       - (2) Use?
     - (e) Ventricles.
       - (1) Number?
       - (2) Use?
   - (3) The Arteries. (See Physiology.) Identify the firm, elastic aorta and its branches, and trace them to the organs which they supply.

(4) The Veins. (See Physiology.) Identify the flabby veins and trace them from their origin in the organs from which they carry the blood to the ascending and descending venæ cavæ, and to their junction with the heart.

(5) Trace the blood from the left ventricle to all parts of the body, naming the principal branches of the aorta, and the principal veins back through the lungs to the starting point, the left ventricle. See some good figure in physiology for the names of arteries and veins.

5. The Digestive System.

(1) The Mouth.

(a) Shape?
(b) Size, large or small?
(c) Contents?
(d) Use?

(2) The Pharynx.

(a) Shape?
(b) Size?

The pharynx leads into a dilatable, muscular tube, the esophagus.

(3) The Esophagus. Thrust a probe down the rabbit's throat. Cut along the neck and follow the esophagus. Note the windpipe or trachea, and its position as related to the esophagus, but do not injure it.

(a) Shape?
(b) Size, length, and diameter?
(c) Opens into what?
(d) Use?

(4) The Stomach.

(a) Shape?
(b) Size? Which end is the larger?
(c) How many openings?
(d) Use?

(5) The Liver is a large dark-colored organ.

(a) Shape?
(b) Size?
(c) Number of lobes?

(d) Location?
(e) Use?
(f) Gall-bladder.
(1) Identify it and trace its duct to the intestine.
(2) What is the function of the bile?

(6) The Omentum. Behind the liver is a broad fold of transparent membrane, the omentum. It is suspended from the posterior border of the stomach and contains fat.
(a) What is the use of the omentum?
(b) What lies behind it?

(7) The Small Intestine.
(a) The *Duodenum*. Joined to the *pyloric* or posterior end of the stomach is the duodenum.
(1) The Pancreas is in the loop of the duodenum. Describe it. Its use? Trace the duct or ducts. Into what do they lead?
(2) The Mesentery holds the folds of the intestines in place. Describe it, noting any blood-vessels. To what is it attached? Of what is it a fold or continuation?
(3) The Spleen is a small red organ in the mesentery, near the cardiac or anterior end of the stomach. Identify it. What is its use?
(b) The Ileum. From the duodenum to the entrance of the cecum is the *ileum*. Cut the mesentery and unravel the small intestine until you find the place where it joins the large one.
(1) How many inches or feet long is it?
(2) Why so long?

(8) The *Cecum* is a very large portion of the intestine, ending blindly.
(a) How long is it?
(b) Why so large?

(9) The Large Intestine. Trace it to the vent.
(a) How does it compare in size and length with the small intestine?
(b) Total length of the alimentary canal? Why so long?
(c) Does the rabbit eat vegetable or animal food?

(10) Sketch the alimentary canal. Name in order all its parts.

6. The Respiratory System.

Draw out the tongue and look behind the *epiglottis*, down into the *larynx*, and find the *vocal cords*. The slit between them forms the *glottis*.

(1) The Trachea.
  (a) Its structure?
  (b) Into what does it divide before reaching the lungs?

(2) The Lungs. Cut through the diaphragm.
  (a) Size?
  (b) Shape?
  (c) Capacity?

(3) Sketch the respiratory organs and name the parts.

7. The Excretory System.

(1) The Kidneys. Remove the digestive organs and identify the bean-shaped kidneys.
  (a) Size?
  (b) Arrangement, alternate or opposite? Any advantage from this arrangement?

(2) The Ureters. Identify the tube leading from each kidney to the bladder.

8. The Reproductive Organs now remain. These may be easily identified.

9. The Osseous System or Endoskeleton.

Carefully dissect off all the flesh and viscera, and leave the bony skeleton entire, clean, and uninjured. By the use of wires and double-pointed tacks, mount this skeleton in its proper position on a nicely planed pine board.

Consult some good figures and name all the bones.

(1) The Skull.
  (a) Are the bones distinct or fused together?
  (b) Notice the edges of the contiguous bones. Are these wavy, zigzag, or straight?
    (1) What are such joints or unions called?
    (2) How are the bones of the human skull united? (See human skeleton or Physiology.)

(2) The Spinal Column.
  (a) Number of cervical or ribless vertebræ just posterior to the skull?
  (b) Number of thoracic or rib-bearing vertebræ?
  (c) Number of lumbar vertebræ—separate vertebræ following the ribs?
  (d) Number of sacral vertebræ fused together?
  (e) How many caudal (tail) vertebræ?
  (f) Note the shape of the vertebræ in different regions. What differences in the length of their spinous processes? Of their transverse processes? Why these differences?
(3) The Ribs.
  (a) How many true ribs, that is, articulated with the sternum?
  (b) How many false ribs?
  (c) Total number of ribs? How many in man?
  (d) Use of the ribs?
(4) The Pectoral Girdle.
  (a) Complete or incomplete?
  (b) What bones present?
(5) Fore Limbs.
  (a) Name the bones.
  (b) Which is the longer, the humerus or the ulna?
  (c) Radius.
    (1) Notice its articulations.
    (2) Is the proximal end internal or external to the ulna?
    (3) The distal end?
    (4) Can the rabbit carry its food to its mouth as a squirrel does? Why?
  (d) The Foot.
    (1) What part of the front foot rests upon the ground in locomotion?
    (2) How many carpal bones?
    (3) Metacarpals?
    (4) Phalanges?

(6) The Pelvic Girdle.
  (a) Identify the three bones, ilium, ischium, and os pubis, in each side of the pelvic girdle.
  (b) Why are these bones so firmly ankylosed together?
  (c) Function of the pelvis?
(7) The Hind Limbs.
  (a) Which segment is longest?
  (b) How long is the tibia, compared with the fibula?
  (c) How are they united?
  (d) With what is the fibula united below?
  (e) What part of the hind foot does the rabbit rest upon the ground when in locomotion?

10. The Nervous System. If it is desired to work out the nervous system, take a fresh specimen. Skin it, remove the internal organs, and follow the directions under the Nervous System in the study of the frog.

SYSTEMATIC STUDY OF THE RABBIT

For study of Branch and Class characteristics, see studies of *Chordate* Branch and Class Characteristics, p. 128.

Study of Ordinal Characteristics

Have for reference several different species of the order to which this animal belongs. If not present for reference, name and have in mind several different species of the order.

1. The Exoskeleton or Covering.
  (1) Do you discover any ordinal modifications of the class covering? If so, what?
  (2) Of what use is it to this order of animals?
2. The Head. What ordinal peculiarities do you discover as to the size, shape, or appendages (horns, tusks, etc.) of the head?
3. The Teeth.
  (1) Present or absent?
  (2) Kind of teeth present (incisors, canines, molars)?
  (3) What does the kind of teeth indicate as to the food and feeding habits of this order?
  (4) If it has no teeth, what substitute does it possess?

4. The Limbs.
   (1) What modifications, if any, of the anterior limbs? or digits?
      (a) Digits clawed or unclawed?
      (b) For what are they adapted?
   (2) What modifications, if any, of the posterior limbs? For what are they adapted? Digits?
   (3) Is the animal plantigrade, or digitigrade, or neither?

5. The rabbit (or mammal used) belongs to Order ..... because it has the following characteristics of Order ..... (Student name them.)

MAN

Habitat.—How does man's habitat differ from that of any other animal? Why?

Food.—Take 4, General Preliminary Study.

Locomotion.—What is peculiar regarding the position and locomotion of man?

What methods of moving from place to place does man have which other animals cannot have except through the agency of man? Why?

Self Defense.—Is man naturally so well fitted for self defense as some other animals? If any other animals have better adaptations, name them. Explain this.

Rivalry.—What means of rivalry has man?

Do we find any mimicry?

Are there warning or alluring colors among men and women? If so, give examples.

Parasitism.—What parasites has man?

Did you ever see a parasitic man? What was the effect?

Environment.—Are man's activities influenced by the weather and by climate? How?

If man's environment does not suit him, what may he do instead of migrating or hibernating?

Name some environment influences that tend to make man migrate.

Distribution.—Geographic?

Geologic? (See Geology.)

Barriers to distribution? Why so few?

MORPHOPHYSIOLOGIC STUDY

Of what does the dermal system of man consist?

Does man molt?

How does man's locomotory system compare with that of other animals? Is it surpassed by that of any other animal? If so, how?

Trace the development of the circulatory organs from Amœba to and including man.

In same manner trace the development of the digestive organs.

Trace, likewise, the respiratory organs.

Trace the nervous system also.

Trace each sense organ from its first appearance to its highest stage of development.

Which of these are more highly developed in other animals than in man? In what animals?

Mind.—Use the Animal Behavior Study, making necessary modifications or omissions.

The Moral Nature.—Do animals have a code of morals?

Does a horse or dog ever steal, as he views it?

Classification.—Classify man, naming branch, class, order, and scientific name, and giving reason for each step in the classification.

Conclusion.—What do you conclude man has in common with other animals?

In what is he superior? Inferior?

PROTOZOA

Suggestions for Laboratory Work.—Specimens of Amœbæ may be found upon the slimy coating of stems which have been standing for some time in water, or upon submerged leaves, or "on the slimy ooze upon the mud at the bottom of standing water," upon the under side of lily pads or along their stems, or from the scum found on the inside of old water-barrels.

The Paramæcium may be obtained by soaking in pond water, for a week, in a warm place, hay which has been cut in pieces. A scum will appear. With a pipette place a drop of this scum under the microscope and follow the outline given below, or verify the points mentioned in the text.

MORPHOPHYSIOLOGIC STUDY

1. The Body is one-celled.
   (1) Shape?
   (2) Size?
   (3) Fixed or free?
   (4) Naked (as in Amœba), or covered with cilia, or with a shell?
2. Appendages of the body. If any, called what?
3. Motion. In the higher forms, motion is carried on by means of (1) the muscular system, and (2) the skeleton. How are motion and locomotion carried on by this one-celled protozoan?
4. Nutrition of the Body. Digestion, circulation, respiration, excretion—how are these processes carried on, since this is a one-celled animal and has no organs?
5. Multiplication. Is it asexual, sexual, or does it multiply both asexually and sexually?

6. The Nervous System. Since it is a one-celled animal, it has no differentiated nerve cells.

(1) Has it irritability? How shown? Use?

(2) Automatic actions. Name those of this animal. Why automatic?

(3) Reflex actions. Name those of this animal. Why reflex?

7. Sketch an Amœba, showing its pseudopodia.

8. Classification of Amœba. Consult descriptive zoölogies for the branch and class of Amœba.

PORIFERA

MORPHOPHYSIOLOGIC STUDY

Laboratory exercise on the Bath Sponge.

Suggestion.—Select "hard head" sponges that have been mutilated as little as possible.

1. The Body is many celled and has an inner and outer germ-layer, and a middle, undifferentiated one, the mesoglea.
   (1) Shape?
   (2) Size?
   (3) Color?
   (4) Sessile or free? Can you tell from your specimen whether or not it has been fixed to some object?
   (5) Naked or covered? If covered, what is the covering called?
   (6) Skeleton. With a compound microscope, examine some of the fibers of the sponge. Do you find any spicules?[1]
2. Appendages. If any, called what?
3. Motion and locomotion. The sponge is free in its larval state. How is locomotion then carried on?
4. Nutrition.
   (1) Cut from the osculum to the cloaca, the large interior space, and count the canal systems. The number of oscula indicates the number of individual sponges.
   (2) Is there any connection between the small inhalent pores and these canals? Why?
   (3) As it has no well-defined systems, how are the processes of digestion, circulation, respiration, and excretion carried on?
   (4) What is its food? How obtained?[1]
5. Multiplication.
   (1) Asexual? If so, by what? Budding, fission, etc.
   (2) Sexual? If so, are the sexes separate, or is the sponge hermaphroditic?

[1] See Part II, "Economic Zoölogy," page 11.

6. The Nervous System. It has no differentiated nerve cells.
   (1) Has it irritability? How shown? Use?
   (2) Automatic actions. Name those of this animal.
   (3) Reflex actions. Name those it has.
7. Make a sketch of one complete canal system.
8. See text for Summary of Branch and Class characteristics of Porifera.

CŒLENTERATA

MORPHOPHYSIOLOGIC STUDY

Suggestion.—This study may be adapted for the study of any Cœlenterate by omitting some questions and enlarging upon others. The Hydra is probably the most easily obtained, and makes a good study of this branch.

Collect from quiet streams or ponds, duck-weed or other water plants. Place them in a large glass jar and put the jar where the light will shine upon it. The hydras will collect on the lighted side, as they are positively heliotropic.

Break off a tiny piece of stem or leaf supporting a hydra. Place it upon a slide with a little water and watch it for several minutes. Does it change its position? When it is extended, touch it with a needle. What does it do?

1. The Body.
   (1) Is it one celled or many celled?
   (2) Size. How long is your specimen? (Length in inches or fraction of an inch.)
   (3) Shape. Is it tubular, or what shape is it? Broad or slender?
   (4) Is the body fixed or free? If fixed, by what portion of the body? How? Is it temporarily or permanently attached? Carefully push it loose with the handle of your scalpel. What does it do?
   (5) Closed or open? If the body is open, describe its opening and give its position on the body. (Use the hand lens for this, or, if necessary, place your specimen on a slide in a drop of water, put a thread or tiny broom straw on each side of the hydra, and cover it with a cover-slip, resting the edges of the cover upon the threads or straws to avoid injuring the specimen, and continue your study under the low power of the microscope.)
   (6) Color. What is the color of your specimen? Is it of uniform color on all parts of the body?

(7) Symmetry. Is this animal asymmetric, radially or bilaterally symmetric, or is it both radially and bilaterally symmetric?

2. The Appendages, or Tentacles.
   (1) Number?
   (2) Shape?
   (3) Are they hollow or solid?
   (4) Where and how are they arranged?

3. Locomotion and Motion. In the Cœlenterates there is a differentiation of muscle-cells and unstriped muscle-fibers.
   (1) Has this animal any locomotion? If so, how is it accomplished? By body movement, or by movement of appendages, or by both? Describe accurately the successive steps in locomotion.
   (2) What motions—aside from locomotion—has this animal?
   Place a tiny particle of meat on the tip of a tentacle. What does the tentacle do? Put the meat at the base of the tentacle. What happens?
   (3) The skeleton is the passive system of motion and locomotion in the higher forms.
      (a) Does this animal have a skeleton? If so, of what does it consist?
      (b) What is its purpose?

4. The Nutrition of the Animal.
   (1) What is its food? How is it obtained?
   (2) Is there any vestige of a tube or gullet dipping down from the mouth into the body cavity?
   (3) Are there any divisions of the gastrovascular cavity? Do the tentacles have any communication with the cavity?
   (4) How and where are the processes of digestion, circulation, and respiration carried on? Where is the waste ejected?
   (5) Is there any advancement in the work of nutrition over that in the Amœba and sponge? If so, what?

5. Multiplication.
   (1) The hydra is hermaphroditic. Near the tentacles, look for small, conical projections. These are the sper-

maries. Sometimes, by careful work with the microscope, the sperm cells may be made out in the spermary, or breaking through into the water.

(2) Look for buds. In what different stages do you find them? Sketch.

6. The Skin or Dermal System in the higher forms. The skin is an organ of respiration and excretion.

(1) Does this animal possess a skin? If so, of what use is it to the animal?

(2) Are there any growths of the skin? (if it has a skin), such as cilia, scales, feathers, hair, etc.

7. The Nervous System.

(1) Of what does it consist in this animal?

(2) Use to the animal?

(3) What special senses have you observed this animal use?

(4) Prove that it has a sense of touch.

(5) Prove that it has either smell or taste.

8. Organs of Defense or Offense. Look for tiny swellings of the ectoderm, especially of the tentacles. These are the nematocysts or stinging cells. Place a drop of acetic acid under the cover-slip and watch these cells. What takes place?

SYSTEMATIC STUDY

1. Body segmented or unsegmented?
2. Symmetry?
3. Plan of structure of body and appendages of this animal?
4. Multiplication?
5. Means of defense?
6. The Cœlenterate belongs to Branch Cœlenterata, for it has the following branch characteristics common to sea-anemone, hydra, coral, polyps, and jelly-fish: (Student fill blanks 1–5.)

(1) As to body,.....

(2) As to appendages,.....

(3) As to plan of structure,.....

(4) Multiplication, by.....

(5) Defense, by means of.....

7. Remark.—The object of this systematic study is to discover the Cœlenterate Branch Characteristics.

ECHINODERMATA (THE STARFISH)

MORPHOPHYSIOLOGIC STUDY

A. External Morphology

1. General Shape? Use of this shape to the starfish?
2. Symmetry.
   (1) Radial or bilateral?
   (2) Advantage of this?
3. Arms or Rays.
   (1) Number in your specimen?
   (2) Size?
4. Aboral Surface. The surface upon which the mouth is situated is called the oral surface, and the surface opposite the mouth, the aboral surface.
   (1) Shape of the aboral or upper surface? Use?
   (2) Aboral Spines or Projections.
      (a) Shape?
      (b) Number?
      (c) Use?
   (3) Madreporic Plate. Look between the bases of two of the rays for a wart-like or sieve-like plate.
      (a) Color?
      (b) Use?
      (c) Into what do its perforations lead?
   (4) Pedicellariæ or pinchers. These are soft, flexible projections among the spines. Scrape off a little of the spiny mass. Mount it in water on a slide, and examine under the microscope ($\times$ 100).
      (a) Estimate the number on one ray.
      (b) Position?
      (c) Structure?
      (d) Use?
   (5) Sketch the aboral surface (1), naming all parts studied.

5. The Oral Surface.
   (1) Shape of the oral surface as compared with the aboral surface? Why this difference?
   (2) Spines.
      (a) Shape?
      (b) Position?
      (c) Arrangement?
      (d) Use?
   (3) Ambulacra, or tube feet. In the groove of each arm or ray observe soft disk-shaped structures.
      (a) Shape?
      (b) Size?
      (c) Number of rows?
      (d) Number in each row?
      (e) Total estimate for the entire animal?
      (f) How are these tube feet used? These tube feet will be further studied in the internal dissection.

6. The Nervous System. Find a whitish or yellowish cord in the ambulacral groove of each ray.
   (1) Trace it to its termination distally.
   (2) Trace it to its termination proximally. With what does it here unite?
   (3) Senses. Find the "eye-spot" at the distal end of each ray.
      (a) Color?
      (b) Use?
   (4) Sketch plan of nervous system.

7. Skeleton.

Examine a dried specimen or, lacking that, dry a portion of a ray for two or three days, then find the calcareous plates and sketch the plan of structure for the skeleton.

B. Internal Morphology

Cut along both edges of each ray. Lay each flap back, or remove it, taking care not to injure the delicate organs or the madreporic plate. Dissect under water.

1. The Digestive System.
   (1) The Mouth. On the oral or under side, find the mouth.
      (a) Size?

(b) Shape?
(c) Any teeth?

(2) The Stomach is a large sac-like organ filling most of the disk. Inflate it or fill it with water to distend it. Does any part of the stomach reach out into the rays?

(3) Hepatic Ceca, digestive glands or livers. In each arm find elongated, branched brown or green bodies or organs.
(a) Size?
(b) Shape?
(c) Position?
(d) Number in each arm?
(e) Where do they unite?
(f) Into what do they empty?
(g) Use?

(4) The Mesentery. Trace it as it holds the ceca together and suspends them from the aboral wall.

(5) The Extensor Muscles. Find them along the center of a flap of a ray which you have turned back.
(a) Shape?
(b) Color?
(c) Size?
(d) Use?

(6) The Intestines are slender and short, leading from the stomach to the vent.
(a) Why are they so short and weak?
(b) How does the starfish feed?
(c) What is its food?

2. The Reproductive System. The reproductive organs or gonads are found along with the hepatic ceca in the floor of each ray. They are usually smaller and more grape-like.
(1) Shape?
(2) Size?
(3) Color?
(4) Number?
(5) Where do they unite?
(6) Use?

3. Sketch the plan of the digestive and of the reproductive systems.

4. The Water Vascular or Ambulacral System is the means of locomotion.

(1) The Ampullæ. Along the floor of each ray of an injected specimen find numerous vesicles or sacs.

(a) Shape?
(b) Size?
(c) Color?
(d) Number of rows? Number in each row?
(e) Total number for the ray? Estimated number for the starfish? Use?
(f) How are these ampullæ connected with the tube feet?
(g) How are they (the ampullæ) connected with each other?

(2) Sketch plan of the ambulacral system.

SYSTEMATIC STUDY FOR BRANCH ECHINODERMATA

1. Plan of Structure. Look carefully at the sea-urchin and sea-cucumber and others for the plan of five in the divisions or organs of the body.

2. Symmetry. Radial, or bilateral, or both?

3. Water Vascular System. Present or absent?

4. The..... (animals examined) have the following branch characteristics: (Student name them.) Hence they belong to Branch Echinodermata.

SYSTEMATIC STUDY FOR THE CLASSES OF ECHINODERMATA

Use a starfish, a sea-urchin, a sea-cucumber, or good pictures of the representatives of other classes.

1. Is this animal fixed or free?

2. Body with central disk and pentameral rays, globular without rays, long and cylindric, or with an acorn-like top on a long flexible stalk?

3. Arms or rays.

(1) Number?
(2) Are the cecal processes contained in the arms?

4. Tentacles present or absent?

5. This animal has the following characteristics:..... hence it belongs to Class.....

Remark.—Consult descriptive zoölogies for Classes of Echinodermata.

ANNULATA

STUDY OF LIVE EARTHWORMS

1. Collecting.
   (1) Habitat. Dig for earthworms in various kinds of soil—loose and open, compact, rich, poor, wet, and dry soils.
      (a) In which soil are the earthworms most numerous?
      (b) How do their depths in these soils vary?
   (2) Homes or burrows.
      (a) In what direction do the burrows extend? Is there any connection between them?
      (b) Are they lined? If so, with what?
      (c) Do the earthworms stop up the entrances to their holes? If so, with what?
      (d) How large are their holes? Why are they of this size?
      (e) Is there any food stored up in these burrows? If so, what?
      (f) Carefully dig up a cubic foot of soil where you find the earthworms numerous, let it dry thoroughly, then break it in two.
         (1) Trace the burrows.
         (2) Sketch a section, showing several.
         (3) How many openings do you find at the surface on a square foot? How many would there be at the same rate in an acre?
   (3) Activities.
      (a) Do you find the earthworms active in the daytime?
      (b) Take a lantern and look for them at night, going very quietly.
         (1) Do you find them out of the burrows at night? Look carefully and see if they are entirely out of them. Try to pull one out. What does it do? How?

(2) What are they doing outside of the burrows?
(3) Try experiments by making different kinds of noises, such as halloaing, clapping the hands, beating tin-pans, etc., to find out if they can hear. Do not get so close as to jar them.
(c) Now try stamping the ground near them, or otherwise jar them strongly. What do they do? How?

2. Laboratory Study.
(1) Take a wide-mouthed jar (candy, museum, or battery jar), nearly fill it with black soil, and firm it down well. Keep it cool and moist, not wet, Put thirty or forty earthworms on top of the soil and watch what they do. Cover the jar with fine wire screen and allow it to stand undisturbed until night.
(2) Foods and Feeding.
(a) In the evening place small bits of various kinds of vegetables, lean and fat meat, etc., on the surface of the soil, to find out whether they are carnivorous, herbivorous, or omnivorous.
(b) Do they choose their food by taste, smell, or feeling?
(c) Where do they feed? In or out of the burrows?
(d) When do they feed?
(3) Influence of light. Set the jar where one-half of it will be in a bright light, and the other side in the dark, or cover one side. Which side of the jar do the earthworms prefer, the light or the dark side?
(4) Locomotion.
(a) Lay the earthworm on a wet paper and note its motions.
(b) Does it accomplish any locomotion? How?
(c) Can it move backward? If so, just how?
(d) Try (a), (b), and (c) again, this time placing the earthworm on a clean piece of glass. Results. Turn it over on its back. What does it do? How?
(5) Sensitiveness.
(a) What portion of the surface of the body is most sensitive to light?
(b) Most sensitive to touch? Is any portion not sensitive to touch?

MORPHOPHYSIOLOGIC STUDY

A. External Morphology

1. Shape? Use of this shape to the animal?
2. Size.
   (1) Length of earthworm when quiet? When extended?
   (2) Thickness laterally? Dorsoventrally?
   (3) How does the thickness compare with the length?
3. Covering. Is the skin naked or covered? If covered, with what?
4. Surfaces.
   (1) Shape and color of the dorsal surface? Use?
   (2) Shape and color of vental surface?
   (3) Do these surfaces differ in shape and color? If so, why?
5. Somites or Segments.
   (1) Number?
   (2) Are they similar in different regions? Why?
6. Cingulum, Girdle, or Clitellum—a swollen region near the anterior end.
   (1) Over how many somites does it extend?
   (2) Does it extend entirely around the body?
   (3) Use to the earthworm?
7. Setæ or Feet on ventral side. Use hand lens or feel them along the ventral surface.
   (1) How many to each somite?
   (2) Upon how many somites are they found?
   (3) How many rows in all?
   (4) How many setæ on the entire earthworm?
   (5) Use of these setæ?
8. Openings in the Body Wall. Identify as many as you can with the hand lens.
   (1) Mouth at anterior end.
   (2) Vent at posterior end.
   (3) Seminal receptacles. Look for them with hand lens about the 9th–11th somites.
   (4) Oviducts. Look for them about the 9th somite.
   (5) Vas deferens, about the 15th somite.
   (6) Dorsal pores—along the dorsal surface.
   (7) Nephridial openings—one pair to each somite.

B. Internal Morphology

1. Pin a dead worm on a wax-bottomed pan or on a sheet of cork, or on a soft pine board, and sink it in the water. With sharp scissors cut through the body wall along the median dorsal line. Spread out and pin down the body wall, exposing the internal organs.

2. Body Wall.
   (1) Thickness?
   (2) Of how many layers does it consist?
   (3) Use of each layer?

3. Body Cavity or Cœlom. Between the body wall and the alimentary canal is a great cavity divided into compartments by the muscular partitions.

4. Circulatory Organs.
   (1) In a live specimen, find (with the hand lens) the dorsal blood-vessel along the dorsal side.
      (a) In what direction does the blood flow?
      (b) Extent of this tube?
      (c) Its branches—how many? These are called "hearts" or aortic arches. (Segments 6–10.)
   (2) Ventral blood-vessel. Below the alimentary canal, find another vessel. How does the blood flow in this blood-vessel—forward or backward?
   (3) Sketch the internal organs, using red for blood-vessels, yellow for alimentary canal, and blue for nerves. Make a sketch one inch in diameter, or draw it on the board.

5. Alimentary Canal, or Digestive Organs. Parts in order: Mouth, pharynx, esophagus, crop, gizzard, stomach-intestine.
   (1) The mouth—in somites one and two.
      (a) Shape?
      (b) Size?
      (c) Use?
      (d) Any teeth?
   (2) The pharynx—in somites 2–7. (a), (b), (c) as for mouth.
   (3) The esophagus—about somites 6–15. (a), (b), (c).

(4) The crop—about somite 15. (a), (b), (c).
(5) The gizzard—about somite 17. (a), (b), (c).
(6) The stomach-intestine—from about somite 17 to end of body.
  (a) Shape?
  (b) Size?
  (c) Use?
  (d) Length?
  (e) Diameter?
  (f) Straight or coiled?
  (g) Pouched or straight?
  (h) Color?
  (i) Contents?
  (j) Typhlosole, or longitudinal ridge in the intestine (a). Shape?
(7) What is the function of the alimentary canal?
(8) What is the specific function of each of its parts? Do not say "aids digestion," but tell just what part in the work of digestion each organ performs.

6. Respiratory System. Respiration is carried on through the whole body surface. The skin is filled with a network of blood-vessels. These vessels take up the necessary oxygen and give off the waste matters to the air. Is the earthworm poikilothermal or homoiothermal? Why?

7. Nervous System. Below the intestines is found the nerve cord.

(1) Trace it to the posterior end of the body.
  (a) Is it a double or a single cord?
  (b) Do you find a ganglion to each somite?
(2) Trace it to the anterior end of the body.
  (a) Do you find one or two ganglia to each somite?
  (b) Does the nerve cord continue as a single cord to the end of the body?
  (c) If it divides, where? What is the destination of each branch?
(3) Cerebral Ganglia. Look for them on the dorsal side, about the second or third somite. Trace their branches.

(4) Sketch the nervous system of the earthworm. What is its use?
(5) Special Senses.

8. Excretory System. The Nephridia. Look for little white, coiled tubes between the septa.
(1) Trace one.
(a) Where does it open?
(b) Use?

C. Cross-section

1. Dorsal Wall.
(1) Cuticle—thin, iridescent.
(2) Epidermis.
(3) Dermis.
(4) Circular muscles.
(5) Longitudinal muscles.
2. Cœlom or Body Cavity.
3. Dorsal Blood-vessel.
4. Alimentary Canal.
5. Ventral Blood-vessel.
6. Nerve Cord.
7. Ventral Wall.
(1) Longitudinal muscles.
(2) Circular muscles.
(3) Dermis.
(4) Epidermis.
(5) Cuticle.

Sketch this cross-section and show all the parts 1–7.

MOLLUSCA

STUDY OF A LIVE FRESH-WATER CLAM OR MUSSEL

1. Collecting.
   (1) Mussels may be found in the shallow water of our ponds and streams, where they are often partly embedded in the sand or mud.
   (2) They may sometimes "be obtained by a long-handled rake from the shore or from a boat."[1] But the surest plan is to don rubber boots and wade out after them.
   (3) As soon as they are captured place them in water and carry them to the laboratory, and put them in the tank with a few inches of sand and several inches of water in the bottom.
2. Laboratory Study.
   (1) Locomotion.
      (a) Watch carefully to discover just how a clam moves itself along.
      (b) Does it leave a track? If so, describe it.
      (c) What is the direction of its progression?
      (d) What is the rate of its progression?
      (e) Place your finger in the sand across the path in front of the mussel and, by allowing it to pass over your finger, find out how the "foot" is used.
      (f) Quickly pick up a mussel in locomotion. Note its foot. What does it do?
      (g) Lay a clam on its side on a piece of glass or smooth wood.
         (1) What does it do?
         (2) Can it resume its natural position and creep away? Explain.

[1] Galloway's "Zoölogy."

(2) Siphons. Notice the fringes of the posterior margins of the mantle. Place a tiny drop of ink above the opening of the siphon and note the direction of the current of water.

(3) Sensitiveness.

(a) Gently touch the margins of the siphons. Are they sensitive to touch? What do they do?

(b) Find out, by experiment, if they are sensitive to light.

(c) Find out if they are sensitive to jars or to currents of water.

MORPHOPHYSIOLOGIC STUDY OF THE CLAM

A. External Morphology

1. The Shell externally.

(1) Shape? Use of this shape to the clam?

(2) Length?

(3) Depth (dorsoventrally)?

(4) Width (laterally)?

(5) Weight of clam with shell?

(6) Weight of clam without shell?

(7) Shell is what per cent. of weight of whole clam?

(8) Why so much shell? Advantage?

(9) Why so little body? Advantage?

(10) Disadvantage of so much shell?

(11) Covering of the shell.

(a) Color?

(b) Use?

(12) Hold the shell in your left hand with the two projections (umbones) from you. The valve in your left hand is the left valve, the one in your right hand is the right valve.

(a) How do the valves agree?

(b) How do they differ from each other?

(13) Concentric lines of growth about the umbones.

(a) How many?

(b) Age of your specimen?

(c) Do you find other ridges in the shell?

(d) Use?

(14) The Hinge Ligament. The anterior end of the shell is blunter than the posterior, the dorsal is thicker than the ventral. Identify the hinge ligament dorsally between the valves.
  (a) Color?
  (b) Structure?
  (c) Use?
(15) Sketch one valve externally and indicate all the points so far made out.

2. The Shell internally.
  (1) Color?
  (2) Structure?
  (3) Surface?
  (4) Any pearls? Theory of the formation of pearls?
  (5) Any lines?
  (6) Teeth of the shell.
    (a) How many in right valve? In left?
    (b) Use of these teeth?
  (7) Muscle scars.
    (a) How many?
    (b) Where are they found?
    (c) Use? By what muscles?
  (8) Sketch inside of the shell and indicate all markings.

B. Internal Morphology

Kill the clam in water gradually heated to about 140° F. The muscles relax, the foot protrudes, and the clam is easily exposed to view for study. The clam may be killed by inserting a strong knife between the valves near the anterior end of the shell and severing the muscles which hold the shell closed.

1. The Clam inside the shell.
  (1) The mantle is found covering the body and adhering to the valves of the shell. Separate the mantle from one valve by inserting a scalpel between them.
    (a) Shape?
    (b) Attachment?
    (c) Use?
  (2) The gills are leaf-like organs under the mantle.

(a) Number?
(b) Attachment?
(c) Use?
(d) Young. One pair of gills may be much enlarged and filled with young clams, called Glochidia. If present, examine under low power of the microscope.

(3) The Labial Palpi. These are small leaf-like organs anterior to the gills.
(a) Number?
(b) Size?
(c) Use?

(4) The Siphons. The mantle is modified posteriorly into two tubes or siphons. The upper one is the excurrent and the lower is the incurrent one. A live clam placed in a vessel containing sand covered with water will show the incurrent and the excurrent stream of water, especially if a little coloring-matter is cautiously added. Use of these siphons?

(5) The Body. The soft body with its projecting foot is now exposed.
(a) Shape?
(b) Size?
(c) Structure?
(d) Segmented or unsegmented?

(6) The Foot. Identify it.
(a) Shape?
(b) Size?
(c) Structure?
(d) Use?
(e) How does the clam use it?
(f) Where must it live to use it?

2. The Internal Organs.
(1) The Digestive Organs.
(a) The mouth is between the palps. Insert a small probe.
(1) Teeth?
(2) Tongue?
(b) The Esophagus leads from the mouth into the stomach.

(1) Size?
(2) Length?

(c) The Stomach.
(1) Size?
(2) Shape?
(3) Use?

(d) The Intestines. Find their beginning at the posterior end of the stomach, trace them through the heart, thence throughout the body. Are they coiled or straight?

(e) The Liver or Digestive Gland is lobed and surrounds the stomach.
(1) Size?
(2) Use?

(f) The Excretory Organs are the kidneys or organs of Bojanus. These organs are dark colored and lie near the pericardial cavity.
(1) Size?
(2) Use?

(g) Sketch and name the digestive organs.

(2) The Respiratory Organs, the gills, have been studied.

(3) The Circulatory Organs. The heart may be seen to pulsate slowly in a specimen just opened. It is on the dorsal side and may be seen through the mantle, lying in the pericardial cavity. The heart consists of the rather lengthy ventricle, through which runs the intestine. The ventricle is joined by two lateral thin-walled, triangular auricles which receive the blood from the gills. The arteries carry the blood to all parts of the body.

(a) Identify and show your teacher the organs of circulation.

(b) Sketch and name all parts.

(4) The Nervous System is rather difficult for beginners, but may be made out in an alcoholic specimen.

(a) Demonstrate to the teacher the following: The cerebral ganglia. Look between the labial palpi at their bases, identify these ganglia, and trace a nerve to the pedal ganglia in the foot near the

mouth. Trace a nerve to a third center, the visceral or the posterior ganglia, near the posterior adductor muscle.

(b) Sketch the plan of the nervous system of the clam.

(5) The Special Senses. Do you find evidence of special senses? If so, of what ones?

A STUDY OF THE SNAIL SHELL

1. Is the shell univalved or bivalved? Why?
2. Is the shell right-handed (dextral) or left-handed (sinistral)?
3. Is the spiral a flat one or a long narrow one?
4. Identify the apex. It is homologous with the umbo of the clam.
5. Identify the lines of growth.
6. How many whorls in your shell?
7. How many sutures has your shell?
8. What gives color to the outside of the living shell?
9. Why are dead shells white?
10. Compare the shell of the clam with that of the snail, giving five points of similarity and five points of difference.
11. Do you see any reason why the clam has a bivalve, the snail, a univalve, and the slug, none, or merely the vestige of a shell?
12. Sketch the snail shell and name all parts present.

SYSTEMATIC STUDY FOR BRANCH MOLLUSCA

1. The Skeleton.
   (1) External, internal, or none?
   (2) If it has a skeleton, of what does it consist?
2. The Body. Segmented or unsegmented?
3. Appendages or Limbs.
   (1) Segmented or unsegmented?
   (2) Number?
4. This animal belongs to Branch Mollusca because it has the following characteristics: (Student name them.)

SYSTEMATIC STUDY FOR CLASSES OF MOLLUSCA

1. Has it a distinct head?
2. If it has a shell, is it a bivalve or a univalve?
3. This animal belongs to Class..... because it has the following characteristics: (Student name them.)
4. Consult descriptive zoölogies for Classes of Mollusca.

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