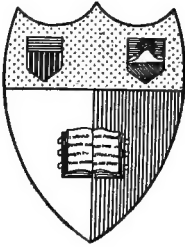


STUDIES OF ANIMAL LIFE

WALTER
WHITNEY
LUCAS

"We must look a long time
before we can see."—THOREAU



Cornell University Library

Ithaca, New York

THE GIFT OF

Cornell University Library
arV17475

Studies of animal life :



3 1924 031 253 788
olin,anx



Cornell University
Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

<http://www.archive.org/details/cu31924031253788>

STUDIES OF ANIMAL LIFE

A SERIES OF LABORATORY EXERCISES
FOR THE USE OF HIGH SCHOOLS

BY

HERBERT E. WALTER, A.B. (BATES), A.M. (BROWN)
NORTH DIVISION HIGH SCHOOL

WORRALLO WHITNEY, A.B. (HARVARD), A.M. (OBERLIN)
SOUTH CHICAGO HIGH SCHOOL

F. COLBY LUCAS, S.B., S.M. (HARVARD)
ENGLEWOOD HIGH SCHOOL

BOSTON, U.S.A.

D. C. HEATH & CO., PUBLISHERS

1900

COPYRIGHT, 1900
BY D. C. HEATH & CO.

PREFACE.

THE following studies are the result of seven years' experience in the high schools of Chicago, where the experiment of applying modern laboratory methods to the study of zoology and botany in secondary schools has already passed through the trial stages and become in some measure an acknowledged success.

As the title indicates, the subject-matter of this book is animal life and not animal forms, the authors' point of view being to study living animals and to interpret their activities, so far as possible, instead of compiling a series of zoological obituaries.

For the majority of high school pupils who do not go to college, being early forced into the active duties of life, zoology has a peculiar mission, since it awakens a healthful interest in living things and aids in forming habits of exact and philosophical observation. It is far more important to make "naturalists" of such pupils than anatomists, consequently all laboratory dissection is omitted. Only advanced pupils showing a decided inclination for such work, or those having some definite purpose in view, should be encouraged to attempt dissection so long as other more congenial avenues of discovery remain unexplored. A briefer comparative study of several related animals seems to lay a better foundation for future additions to the pupil's knowledge than a more exhaustive study of single types.

The use of the compound microscope is essential, not because there is any lack of material which may be studied with the unaided eye, but because many of the fundamental conceptions in the science of life cannot well be gained without its help. Charts, etc., may be used to some extent in place of the microscope, as books of travel must content those who stay at home.

This manual is not designed to take the place of the teacher. Nothing can take the place of a genuine teacher, without whose directing hand and contagious enthusiasm all manuals are dry bones indeed.

It is simply designed to serve as a supplementary aid in laboratory work, and it is hoped that the arrangement and form of these questions is such that more attention will be directed to the animals than the book.

A year's work is here outlined, but by omitting some of the minor studies it can readily be adapted to a shorter time without destroying the symmetry of the course.

A "Teacher's Book of Suggestions" accompanies the manual, in which hints on the pedagogical value of each study and suggestions for the preparation and treatment of the material are given.

We wish to gratefully acknowledge the many suggestions and valuable criticisms of our fellow-teachers in Chicago and elsewhere, and especially our debt to the late Emanuel R. Boyer, the pioneer of laboratory biology in the Chicago schools, at whose suggestion this work was undertaken.

THE AUTHORS.

CHICAGO, June, 1900.

CONTENTS.

	PAGE
PREFACE	iii
TABLE OF ABBREVIATIONS, ETC.	viii
Preliminary Exercises	1
1. The Compound Microscope	1
2. The Cell	4
Study I. PROTOZOA. ONE-CELLED ANIMALS	6
1. Amœba	6
2. Paramœcium. "Slipper Animalcule"	8
3. A Comparative Study of Protozoa	11
Study II. PORIFERA. SPONGES	13
1. A Simple Sponge. Grantia	13
2. A Fresh-water Sponge. Spongilla	15
3. A Toilet Sponge. Skeleton of Euspongia	15
Study III. CŒLEENTERATA. STINGING ANIMALS	17
1. Hydra	17
2. A Campanularian Hydroid	20
3. A Tubularian Hydroid	22
4. A Hydro-medusa	23
Study IV. VERMES. WORMS	26
1. A Planarian Worm	26
2. The Earthworm	27
3. A Marine Annelid Worm	34

	PAGE
Study V. ECHINODERMATA. SPINY-SKINNED ANIMALS	37
1. The Starfish	37
2. The Sea-urchin	39
3. The Sea-cucumber	40
4. The Development of an Echinoderm	40
Study VI. ARTHROPODA. JOINT-FOOTED ANIMALS	42
1. The Crayfish	42
2. The Crab	51
3. The Pill-bug	53
4. The Fairy Shrimp. Branchipus	53
5. The Locust. "Grasshopper"	55
6. The Metamorphosis of a Moth. "Cecropia"	60
7. The Metamorphosis of a Mosquito	62
8. An Exercise in Identification and Classification	64
9. A Comparative Review of the Arthropoda	67
Study VII. MOLLUSCA. SOFT-BODIED ANIMALS	68
1. The Fresh-water Clam	68
2. The Snail	72
3. The Squid	73
Study VIII. VERTEBRATA. BACKBONED ANIMALS	76
1. The Goldfish and Perch	76
2. The Frog	80
3. Tadpoles, a Study of Vertebrate Metamorphosis	92
4. A Study of a Bird Skin	92
5. Vertebrate Exoskeletons	94
6. A Comparative Study of Living Vertebrates	99
7. A Zoological Study of Man	102
8. A Comparative Review of Important Types	104
A TABLE OF CLASSIFICATION	106

TABLE OF ABBREVIATIONS, ETC.



l.p. low power.	Dem. refer to the teacher.
h.p. high power.	cm. centimeter.
l. hand lens.	

- Sketch.** When this term is used, a rapid drawing on the note paper is intended.
- Drawing.** When this term is used, a careful outline drawing is intended. This is to be made on the drawing paper with the hard pencil or a pen.
- Diagram.** This indicates a drawing in which the *relation* of the parts is shown, rather than the form.

LABORATORY AXIOMS.

1. Never make a line in a drawing unless it means something.
2. Always name the parts of a drawing, sketch or diagram.
3. Never be content with a dull drawing pencil.
4. Always use a hard pencil in drawing.
5. Make all drawings natural size, unless otherwise directed.
6. Be orderly and systematic in your work.
7. Ask questions if there is anything you do not understand.
8. Do not be satisfied to answer questions simply "yes," or "no." Give reasons for your conclusions whenever possible.

STUDIES OF ANIMAL LIFE.



PRELIMINARY EXERCISES.

1. THE COMPOUND MICROSCOPE.

A. Parts.

The compound microscope consists of two parts, the mechanical part (**stand**) and the magnifying part (**lenses**).

B. Stand.

1. The **base**, the part which rests on the table.
2. The **vertical column**, attached to the base and supporting the other parts.
3. The **stage**, a horizontal shelf attached to the vertical column. What is the use of the opening in the center of the stage?
4. The **rotary disk**, with openings of different sizes, fastened to the under side of the stage. What is its use?
5. The **mirror**, attached to the vertical column below the stage. What is its use? In how many directions can it be turned?
6. The **sliding tube**, held in a **sleeve**, which is in turn connected with the upper part of the vertical column.

With one hand hold the stand firmly by the base.

With the other slowly raise and lower the tube, at the same time, twisting it toward the right in the sleeve. This method of moving the sliding tube is called the **coarse adjustment**. (The sliding tube should be kept well cleaned so that it will move easily.)

7. The **milled head** at the top of the column. Measure the distance from the end of the sliding tube to the stage. Turn the milled head three revolutions to the right and measure the distance again. This method of moving the sliding tube by means of the milled head is called the **fine adjustment**.

C. Lenses.

1. The **eye-piece**, a small metal cylinder with a lens at each end. It is placed in the sliding tube at the upper end. Hold the eye-piece to the light and look through it. Observe the circle of bright light.
2. The **objectives**, sets of lenses which screw into the lower end of the sliding tube. These objectives vary in magnifying power and are usually distinguished as **high power** (h.p.) and **low power** (l.p.). Find three ways of telling one from the other.

The following precautions should always be observed : —

Never touch the lens with your fingers.

To remove dust from the lens, wipe gently with a clean, soft cloth, preferably a piece of old linen.

If balsam or other adhesive substance is on the lens, do not attempt to clean it yourself, but call the teacher.

Keep all lenses not in use protected from dust.

D. The Use of the Microscope.

1. To get the light.

Place the microscope with the vertical column next to you, the eye-piece in position. Look through the eye-piece and move the mirror until you obtain a bright circle of light (**field of vision**) similar to that obtained when you held the eye-piece to the light.

2. To focus.

Place a mounted preparation on the stage of the microscope exactly over the center of the opening. Remove the sliding tube. Take the low power firmly in your left hand and screw the sliding tube on to it. Replace the sliding tube, and, bending over so that your eye is on a level with the stage, slowly lower the sliding tube by means of the coarse adjustment until it is within a centimeter of the stage. Then, looking through the eye-piece, raise the sliding tube by means of the coarse adjustment until the object comes into view. Next, by means of the fine adjustment, raise or lower the sliding tube until the outline of the object is sharp and clear. Repeat this until you become skilful. (Turn the milled head with the thumb and fore-finger. Never make more than three revolutions of the milled head in the same direction.)

Substitute the high power and proceed as follows:

With your eye on a level with the stage as before, lower the sliding tube by means of the coarse adjustment to within a millimeter of the object. Then by means of the fine adjustment raise the sliding tube until the outline of the object is

clear as before. (Exercise the greatest care in order not to injure the lens.)

SUMMARY OF THE STEPS IN THE USE OF THE MICROSCOPE.

1. Put on the objective.
2. Place the preparation on the stage.
3. Get the light. (Mirror.)
4. Focus. (Coarse adjustment and fine adjustment.)
5. Adjust object in the field.
6. Regulate the light. (Mirror and rotary disk.)

E. Exercises in the Use of the Microscope. (Dem.)

1. Place a preparation of a letter on the stage in such a way that the letter is in the natural position. Sketch the letter in this position without looking through the microscope.
2. Without changing the position of the letter, examine it with the low power (l.p.). Show by a sketch the effect of the microscope on the apparent position of the letter.
3. Use a hand lens. Does it have the same effect as the compound microscope?
4. Use high power (h.p.), and compare the appearance of the letter under high power with that under low power. Which would be better for making a sketch of the entire letter?
When would you use a hand lens? Low power?
High power? In what order?

2. THE CELL.

A. Independent Cells.

1. Ascertain whence the material you are to study was

obtained. Examine these cells (l.p.) and observe,—

- (a) the shape of each cell ;
 - (b) the **cell wall**, a membrane surrounding the cell ;
(This is not always easily seen.)
 - (c) the **cytoplasm**, the portion of the cell within the cell wall ;
 - (d) the **nucleus**, a small body embedded in the cytoplasm. The cytoplasm and nucleus together are called **protoplasm** (living substance).
2. Select a typical cell and make a drawing, 2 centimeters in diameter (2 cm.), to illustrate the points just observed.
 3. Make a clay model to show your idea of the shape of a typical cell.

B. Associated Cells, usually called “**tissue**.”

Ascertain as before whence your material was obtained.

1. Identify cytoplasm, cell wall and nucleus.
2. Explain the difference in shape between an independent cell and a single cell in a tissue.
3. Make a drawing of six adjoining cells, making each cell 2 cm. in its greater diameter.

STUDY I. PROTOZOA. ONE-CELLED ANIMALS.

Central idea: Cellular activity.

1. AMŒBA.

A. Habitat. (Dem.)¹

1. How are Amœbæ cultivated in the laboratory?
2. How and where was the material for their cultivation obtained?
3. How are they prepared for your examination?

B. Shape and Movements.

Find an Amœba in your preparation and watch it carefully for some time.

1. Make a series of outline sketches at intervals of one minute to show the changes in shape which this Amœba undergoes.
2. Can you describe the shape of the Amœba?
3. Does the Amœba change its position? If so, make sketches to show its shape at successive intervals.

The temporary projections which the Amœba puts out in its movements are called **pseudopodia**. Can you apply the term "locomotion" to any of the movements of the Amœba?

¹ Wherever this abbreviation is used apply to the teacher for instructions or information.

Is there purpose in the movements of the Amœba? ¹

C. The Body.

The substance of which the Amœba's body is composed is called **protoplasm**. The outer portion (**ectosarc**) is unlike the inner portion (**endosarc**).

1. In what respects do the ectosarc and endosarc differ?
2. Make a sketch to show the relation of the ectosarc to the endosarc.

How is the ectosarc of advantage to the Amœba?

D. Feeding.

1. Do you observe anything in the ectosarc that might be particles of food? In the endosarc?
2. Can you find the mouth?
Has the Amœba a stomach?
How does the Amœba swallow its food?
Do you think the Amœba can distinguish between what is food and what is not food? Why do you think so?

E. The Vacuole.

A **vacuole** is a clear space in the endosarc. Watch it steadily.

1. Do you notice it disappear and reappear?
2. Is this pulsation regular?
Can you suggest any **function** (use) for the vacuole?

F. The Amœba as a Cell. (Dem.)

1. Identify, —
(a) the **cytoplasm**;
(b) the **nucleus**.

¹ It will be seen that throughout the book unnumbered questions like this cannot be answered entirely by direct observation, but require some exercise of the reasoning powers.

Is the absence of a thickened cell wall of any advantage to the Amœba?

How would you describe protoplasm as seen in the Amœba?

G. Reproduction. (Dem.)

1. Occasionally an Amœba is seen to divide into two equal parts beginning with the nucleus. This is reproduction by **fission** or **division**.

H. Drawings, etc.

1. Make a clay model of an Amœba.
2. By the aid of your observations and sketches make a careful and fully labelled drawing (2 cm.)¹ of an Amœba.
3. Show by drawings the method of reproduction.

2. PARAMŒCIUM. "*Stipper Animalcule.*"

A. First take some time to *become acquainted* with your animals without reference to the following questions. Begin with the naked eye, then use hand lens (l.) and finally the low power (l.p.).

1. How are Paramœcia cultivated in the laboratory?
2. Where was the material for their cultivation obtained?
3. How are they prepared for examination?

B. Shape.

1. Are these animals all shaped alike?

¹The size of drawings will always be designated in centimeters. This drawing should measure 2 centimeters in its greatest diameter.

2. Are they as thick as they are wide? (Watch for them to roll over.)
3. How do the two ends of the animal differ?
4. Can they change their shape so as to squeeze between obstacles?

C. Movements.

1. Can the *Paramecium* swim backwards? (Which way is "backwards"?)
2. Can they swim sidewise?
3. Can they guide themselves and avoid collisions? Do they really swim as fast as they seem to swim under the microscope?

D. Feeding.

1. The Food-balls.
Food-balls are numerous little masses of food distributed throughout the body.
 - a. Are they located in any particular part of the body?
 - b. Do they move about inside the animal? (If they are located exactly alike in all *Paramecia*, you may infer that they do not move about.)
2. The Gullet.
 The **gullet** is a diagonal groove where the food is taken in. It is on the side of the body and is best seen as the animal rolls over.
3. The Food Vacuoles.
 The **food vacuoles** are spaces surrounding some of the food-balls.

E. The Pulsating Vacuoles.

The **pulsating vacuoles** are spaces that disappear and reappear in pulsations.

1. How many are there? (Do not confuse them with food vacuoles.)
2. Where are they situated?
3. Does it take longer for them to disappear than to reappear?
What becomes of them when they disappear?

F. The Animal as a Single Cell. (Dem.)¹

1. Is a definite cell wall discernible?
2. Can you distinguish nucleus from cytoplasm?

G. Reproduction. (Dem.)¹

1. Do you find any animals pinching into two parts, dumbbell fashion? This is "multiplication by **division.**"
2. Do you find any double ones, *i.e.* two *Paramœcia* fused together lengthwise side by side? This is "**conjugation.**"

H. Drawings.

1. Draw an accurate outline (4 cm.)² and include in it only the food-balls and gullet.
2. Draw another similar outline and include in it only the two kinds of vacuoles.
3. Draw the animal as a cell. (F.)
4. Draw anything which you found under G.

I. Suggestive Questions.

1. Why are protozoa so universally distributed?
2. Do *Paramœcia* show any signs of intelligence?
3. Have they any means of self-defence?
4. Are they sensitive to light?

¹ Refer to note under *Amœba A.*

² Refer to note under *Amœba H 2.*

5. Can they distinguish their food?
6. What is the probable use of the pulsating vacuoles?
7. Is there any evidence that *Paramœcia* can breathe?
8. What is the advantage to the animal of so much moving about?

J. Points difficult to make out.

1. The fine vibratory hairlike structures (**cilia**) by means of which the animal moves. (Use h.p., turn the rotary disk to shut off most of the light and look sharply at the edge of an animal that has been "cornered.")
2. The larger cilia lining the gullet. Their movement directs the food particles floating in the water into the gullet.
3. The radiating canals which appear like the spokes of a wheel when the pulsating vacuole disappears. (They are best seen after the animal has been quiet awhile or has been "cornered.")

3. A COMPARATIVE STUDY OF PROTOZOA.

Prepare a table similar to the one indicated below. Place the name of the animal studied at the head of the column and fill in your answers below these headings. Draw a horizontal line across the page after each question to separate it from the one following. Use the two left-hand columns for the topics, printed in blackfaced type, and the number of the question.

TOPIC.	NO. OF QUES- TION.	AMEBA.	PARAMECIUM.	VORTICELLA.	ETC.

A. Shape.

1. Show by a sketch the shape of the animal.

B. Movements.

1. Is the animal fixed in position or free-swimming?
2. What are the organs of locomotion?
3. Can the animal contract? If so, show the contracted condition by a sketch.

C. Feeding.

1. Show by a sketch the location of the mouth, if present.
2. By what means does the animal get hold of its food?

D. The Body.

1. Show by a sketch the animal as a cell.
2. How many pulsating vacuoles are there?

E. Reproduction. (Dem.)

1. Show by a sketch the method of division.

STUDY II. PORIFERA. SPONGES.

Central ideas : Transition to many-celled animals.
Beginnings of division of labor among cells.

1. A SIMPLE SPONGE. *Grantia ciliata*.

A. Habitat. (Dem.)

1. What is the source of this material?
2. In what kind of places on the sea-coast are these sponges to be found?
3. Why cannot living sponges of this kind be secured for your study?

B. General Observations.

Answer questions 1, 5 and 6 by a drawing.

1. What is the shape of this sponge?
2. Is this shape typical for all *Grantiæ*? Examine several specimens before deciding what the typical shape is.
3. What is the exact length in millimeters?
4. What is the average length? Make a definite line at one side of the drawing showing the exact average length of all the sponges measured by the class. (Dem.)
5. Observe the needle or bristle-like structures (**spicules**) projecting from the body.
6. How do the two ends of the sponge differ? One end of the living sponge (**proximal** end) is always attached to some pier, rock or such support while the other end (**distal** end) is free.

C. The Canal System.

The body of the sponge is penetrated by a system of canals and cavities for the passage of water.

1. The **Osculum**, a large opening at the distal end of the body.
2. The **Central Cavity**. (Examine a sponge split lengthwise and one in cross-section.)
 - a. What is the relation of the central cavity to the osculum?
3. The **Canals**, small passages through the body wall leading from the outer surface to the central cavity.
4. The external openings of these canals are called **inhalent pores**, and the internal openings into the central cavity are called **ostia**. Identify the canals and their openings.

What causes the water to flow through the canals? ¹

What is the course of the water through the canals?

Show this by arrows in the diagram for C 5.

5. Make a clay model of a sponge split lengthwise (8 cm.).
6. Make a drawing or diagram (4 cm.) of a sponge split lengthwise, to show the relation of the different parts of the canal system to one another. Label fully. (See *Laboratory Axiom 2.*)

D. Spicules.

1. Are the spicules arranged in regular order in any part of the body? (l. and l.p.)
2. Draw perfect examples, much enlarged, of the different shapes you find. (Dem.)

What is the use of spicules to the sponge?

¹ See footnote on p. 7.

Of what mineral substances are these spicules?
(Dem.)

2. A FRESH-WATER SPONGE. *Spongilla.*

A. Habitat. (Dem.)

1. Where were these sponges collected?
2. If you were collecting, where would you look for the fresh-water sponges and how would you recognize them?

B. The Living Sponge.

1. Has the sponge any definite form? (Examine several specimens.)
2. What is the appearance of the sponge "flesh"?
3. Have the spicules a definite arrangement?
4. Of what mineral substance are these spicules?
(Dem.)
5. Identify the oscula.
Would you call this sponge a **colony** or an **individual**?

C. The Sponge "Flesh."

1. Identify the **cells** which form the sponge flesh. (Dem.)
2. In what respect do these cells resemble *Amœbæ*?
3. Do they form a **tissue**?

D. Drawings.

1. A sponge colony.
2. A sponge cell. (1 cm.)
3. Spicules.

3. A TOILET SPONGE. *Skeleton of Euspongia.*

1. Test the elasticity of the skeleton by squeezing it.
(Use both dry and wet specimens.)

2. The Canal System.
 - a. Identify the oscula and inhalent pores?
 - b. Try to trace canals from the inhalent pores to the central cavities. (Use a split sponge.)
3. Examine a few fibers torn from the skeleton.
 - a. What is their appearance and arrangement?
 - b. What is their composition? (Burn a bit for the odor.)
4. Make a drawing of some of these fibers.
5. In this sponge what corresponds to the spicules of *Grantia* and *Spongilla*?

Suggestive Questions.

1. Where are toilet sponges obtained? How are they gathered and prepared for market?
2. Are sponges ever free-swimming animals?
3. What do sponges eat?
4. How do they obtain their food?
5. Must they breathe?
6. Are sponges protected from their enemies?
7. Classify sponges according to the kind of skeleton.
8. How do you know sponges are animals?

STUDY III. CŒLEENTERATA. STINGING
ANIMALS.

Central idea: Division of labor.

1. HYDRA.

A. Habitat.

1. Observe the Hydræ in the aquaria and note their position in relation to,—
 - (a) the green water-plants in the aquarium;
 - (b) the sides of the aquarium;
 - (c) the surface of the water;
 - (d) the light.
2. Where were the Hydræ obtained? (Dem.)
3. How were they collected? (Dem.)
4. How are they kept in a flourishing condition in the laboratory?

B. Shape and Movements.

1. Show by sketches the various shapes which the Hydra assumes during the course of ten minutes. (Examine several specimens in watch-glasses or test-tubes and in the aquaria. Touch gently some of the specimens or disturb them in some manner.)
2. What is the cause of the changes in shape?
3. Observe the great flexibility of the Hydra.

C. Tentacles and Mouth.

Tentacles are the "arms" at the distal end of the body.

1. How many are there?
2. What is their arrangement?
3. Are they as flexible as the body, and have they the same power to shorten and lengthen themselves?
4. Do they all shorten at once?

The Hydra's **mouth** is situated in the center of the circle of tentacles at the summit of a small elevation.

D. Structure. (Use prepared cross-sections.)

1. Identify, —
 - (a) the central cavity (**digestive cavity**);
 - (b) the body wall surrounding the digestive cavity.
2. The Body Wall.

The **body wall** is composed of two layers of cells, an outer layer (**ectoderm**) and an inner layer (**endoderm**).

- a. Compare the thickness of these two layers.
- b. Identify a very thin partition, not composed of cells, between the ectoderm and the endoderm.
3. Nettle cells. (Dem.)

Nettle cells are pear-shaped cells in the ectoderm which have the power to discharge a thread together with a liquid and thus to paralyze small animals.

- a. Identify the nettle cells.
- b. Where are they most numerous?
- c. What advantage is there in this distribution of the nettle cells?
4. Which of the structures mentioned in 1, 2 and 3 can you identify in a living Hydra?

E. Drawings, etc.

1. Make a clay model of a Hydra.
2. Cut out of paper a model of (1) a cross-section, (2) a longitudinal section. Color ectoderm white or blue, endoderm yellow and the partition-membrane red.
3. Make a careful drawing of a typical Hydra (5 cm.).
4. Make a diagram of a cross-section (3 cm.).

NOTE: Sections F, G and H require observations for several successive days.

F. Locomotion.

1. What evidence can you give that the Hydra changes its position in the aquarium? (Devise some plan for proving this.)
2. Is the Hydra's hold on the jar or leaf easily loosened? (Try to detach a Hydra with a camel's-hair brush.)
3. Does the Hydra drop to the bottom when loosened? By what means does the Hydra move from place to place?

G. Feeding.

1. How does the Hydra seize and swallow food? (Try to feed the Hydra with bits of meat or with small crustaceans.)
2. How is the Hydra able to catch swimming animals? What is the natural food of the Hydra? Where must the Hydra live to find this food most plentiful?

H. Reproduction.

1. Budding.
A small Hydra called the **bud** sometimes grows from the side of another Hydra.

- a.* Is the bud in every respect like the parent Hydra?
 - b.* What becomes of the bud? (Watch it from day to day.)
 - c.* Draw a budding Hydra.
2. Occasionally a Hydra may be seen with little bunches projecting from the surface of the body containing either **egg** or **sperm** cells. Those containing the egg cells are the more distal and are called **ovaries**, while those containing sperm cells are called **spermaries**.

I. Suggestive Questions.

1. In what direction must "contractile fibers" extend to enable the Hydra to shorten itself so quickly?
2. How must they be arranged to lengthen the Hydra's body?
3. Does the Hydra need any special organ for breathing?
4. In what different ways does the Hydra show "**division of labor**"?
5. In what important particulars is the hydra-plan of structure like the grantia-plan?
6. How does the Hydra differ essentially from the Grantia?

J. Extra Work.

1. Examine a thin cross-section of the body wall and draw ectoderm and endoderm cells and also nettle cells.

2. A CAMPANULARIAN HYDROID.

NOTE: Since practically all hydroids and hydro-medusæ are marine in their habitat and since living material can only be obtained near the sea-shore, these studies are based entirely on preserved specimens.

A. The Hydroid Colony.

1. Examine the entire hydroid colony with reference to its general appearance, and fragments of a colony

mounted on slides for details, using l., l.p., or h.p., as necessary.

Parts to identify : —

- a. The branching stem.
- b. The transparent sheath-like covering of the stem (**perisarc**).
- c. The tassel-like structures (**hydranths**) at the ends of some of the branches.
- d. A vase-like body (**gonangium**) at the end of some of the branches. This encloses a cluster of small "buds" (**medusa-buds**).

How much of this colony is a single individual?

On what grounds can the hydroid claim cousinship to the Hydra?

B. A Single Hydranth. (Corresponding to a single Hydra.)

1. Are the tentacles arranged as in the Hydra?
2. Are all the tentacles of the same kind?
3. Can you see nettle cells on the tentacles?
4. Identify the mouth-opening surrounded by tentacles.
5. Does the perisarc surround the hydranth as well as the stem?

C. A Single Gonangium.

This is a hydranth modified for reproduction. The medusa-buds within the sheath of the gonangium break free into the water and by enlarging become **medusæ** (see Number 4 in Study III. on p. 23). These medusæ produce eggs from which develop new hydroid colonies like their grandparent form. This manner of reproduction is called **alternation of generations**.

1. Can a gonangium be said to have a mouth and tentacles in the same sense as an unmodified hydranth?
2. Are the medusa-buds larger at the distal or at the proximal end of the gonangium? Explain why.

D. Drawings.

1. The entire colony.
2. A fragment of a colony enlarged to illustrate A 2.
3. A single hydranth enlarged still more.
4. A single gonangium enlarged.

E. Suggestive Questions.

1. Of what advantage to these animals is this plant-like manner of life?
2. How would the Hydra need to be modified to carry out the hydroid plan?

3. A TUBULARIAN HYDROID.

(See note under Campanularian Hydroid.)

A. The Hydroid Colony.

1. Examine an entire hydroid colony with reference to its general appearance, and fragments of a colony mounted on slides for details, using l., l.p., or h.p., as necessary.
2. Parts to identify : —
 - a. The branching stem.
 - b. The tassel-like structures (**hydranths**) at the tips of the branches.
 - c. Ovoid structures (**medusa-buds**) attached to the hydranths.

B. A Single Hydranth. (Corresponding to a single Hydra.)

1. Are the tentacles arranged as in the Hydra?
2. Are all the tentacles of the same kind?
3. Exactly where are the nettle cells on the tentacles?

4. Observe the digestive cavity outlined through the semi-transparent body wall of the hydranth.
5. Is there a transparent sheath around the hydranth?
6. Where are the medusa-buds attached?
7. Are the medusa-buds of uniform size?
8. Observe the digestive cavity within a large medusa-bud.

These medusa-buds drop off into the water and then enlarge into **medusæ** (see Number 4 in Study III. on p. 23). These medusæ produce eggs from which develop new hydroid colonies like their grandparent form. This manner of reproduction is called **alternation of generations**.

D. Drawings.

1. An entire colony.
2. A fragment of a colony enlarged to illustrate A 2.
3. A hydranth with medusa-buds, enlarged still more.

4. A HYDRO-MEDUSA.

(This is the alternate generation of a hydroid.)

- A.** Observe its general hemispherical shape. The convex side is termed the **ex-umbrella side**, and the animal swims with this side up. The flat side is termed the **sub-umbrella side**.
- B.** Carefully place the specimen with the sub-umbrella side up and make out the following points:—
1. Tentacles.
 - a. A little **pad** near the distal end of each tentacle. (By means of these pads, which act as suckers, the animal attaches itself to the floating seaweeds.)¹

¹ See footnote on p. 24.

Can you see any reason for this animal's scientific name, *Gonio-nemus* = bent-thread? ¹

b. Bunches of nettle cells on these tentacles.

2. Balancing Organs.

The **balancing organs** are tiny sensory structures arranged around the edge of the "umbrella" like a string of beads.

a. Compare the number of these organs with that of the tentacles.

b. What is their arrangement with reference to the tentacles.

3. Prominent convoluted structures. (These contain either egg- or sperm-cells.)

a. How many of these structures are there?

4. The Velum.

The **velum** is a delicate membrane extending inward from the margin.

5. The Manubrium.

The **manubrium** corresponds in position to the handle of an umbrella and contains a part of the digestive cavity.

6. The Mouth.

The opening into the digestive cavity at the end of the manubrium.

C. Drawings.

1. Sub-umbrella view (4 cm.).

2. Side view. (Make it diagrammatic.)

D. Application of Coelenterate Studies.

1. Show by a series of diagrams how the hydro-medusa resembles in its plan of structure the Hydra and also the hydranth of a hydroid.

¹This question applies only to *Gonionemus vertens*.

2. Invent a brief scheme to make clear at a glance the plan of alternation of generations.
3. What is the advantage to a fixed animal, such as a hydroid, in having a free-swimming generation like the hydro-medusa?

STUDY IV. VERMES. WORMS.

Central ideas : Division of labor carried still farther.
The bi-lateral plan of structure.

1. A FLANARIAN WORM.

1. What is its habitat? (Dem.)
2. Distinguish the blunt "head end" (**anterior**) from the opposite pointed end (**posterior**).
3. Distinguish the upper surface (**dorsal**) from the lower surface (**ventral**).

How can you always locate the right and the left side of an animal when you know its anterior end and its dorsal surface?

4. See two tiny spots ("**eye**"-spots) in the antero-dorsal region. These indicate the locality of the nerve centers.

Why has the animal become most sensitive at the anterior end?

5. Identify a short tube lying lengthwise against the postero-ventral region of the body. (The mouth is at the end of this tube.)
6. Identify the large, branching, brownish alimentary canal.

What is the special advantage of this type of an alimentary canal?

7. How does this alimentary canal resemble in plan the digestive cavity of the Hydra?

8. Look for cilia clothing the surface of the body.
(Use powdered carmine to demonstrate their movement.)
9. Do these animals move either backwards or sidewise?

2. THE EARTHWORM.

A. Habitat and Habits.

1. Field Study.

These questions should be answered after observing earthworms in their natural habitat, *i.e.* lawns, vacant lots, gardens, etc. The observations should continue through two or three weeks if possible.

- a.* How can you recognize earthworm burrows?
 - b.* Are these burrows more numerous at one time than another?
 - c.* How deep did you have to dig to find earthworms?
 - d.* What kind of soil do they prefer? Why?
 - e.* Do they like to live either in wet soil or in water?
 - f.* Estimate the number of worms living in an acre of soil or in a vacant city lot (25 x 175 ft.).
 - g.* Why are they so abundant on the surface after heavy rains?
 - h.* Report any other interesting facts which you observed concerning earthworms.
- #### 2. Home or Laboratory Study.

Fill a deep box, about 1 x 2 ft. in size, two-thirds full of loamy soil. Put three or four dozen earthworms in the soil and press it down firmly, leaving the surface smooth. Scatter bits of both *fresh* and *decaying* leaves and other possible food materials over the surface of the soil, together with a few

bits of paper. Cover the box with a glass plate and keep the soil in a moist condition.

Make daily observations for two weeks and keep a written record of all you observe, giving special attention to the following questions.

- a. What was the first evidence that the worms had come to the surface?
- b. How long before the food materials began to disappear?
- c. What disappeared first? What last?
- d. Was the food eaten on the surface or carried below the soil to be eaten?
- e. When do the worms get the food, in daytime or night-time? Why?
- f. What is the final appearance of the surface of the soil?
- g. How have the earthworms changed the character of the soil?

B. General Observations.

(Use live specimens. Preserved specimens should only be used for comparison.)

1. What is the shape of the body?
2. What is the length? (As it is difficult to measure a crawling worm, take the average of at least three measurements.)
3. What is the color?
Would any other color do just as well for the earthworm? Why?
4. Identify the mouth.
Why is this an advantageous position for the mouth of this worm?

C. Segmentation of the Body.

Segmentation is the repetition of ring-like parts of the body of an animal.

1. Is the entire body of the earthworm segmented?
2. Are all the segments (**somites**) of the same size?
3. Do large earthworms have the same number of somites as small ones?

D. The Body Regions.

The forward end of the body of any animal is called the **anterior** end and the opposite end, the **posterior**.

The upper surface of the body is usually called the **dorsal** surface and the lower surface, the **ventral**.

1. How does the anterior end differ from the posterior end in, —
 - (a) shape ;
 - (b) color ;
 - (c) sensitiveness ;
 - (d) muscular power ;
 - (e) use ?
2. How does the dorsal surface differ from the ventral surface in, —
 - (a) shape ;
 - (b) color ?
3. Has the earthworm a right and a left side? How do you know?
4. How can you always tell the right and the left side of an animal? An animal whose right and left sides are similar is said to be **bi-laterally symmetrical**.

What determines whether there is a "head end"?

Why do the dorsal and ventral surfaces differ in shape?

5. How do they differ in color?
What is the advantage of this difference?

E. The Girdle.

The **girdle** is the broad band about the earthworm's body near the anterior end and is concerned in the formation of the egg case.

1. Does it form a complete ring?
2. Do all earthworms have a girdle? How do you know?

F. The Cuticle.

The **cuticle** is the thin transparent covering of the earthworm.

1. Identify it. (Examine both dead and living specimens.)
2. What is the color of the cuticle?
3. Observe (h.p.) small openings and very fine lines in the cuticle.
4. Draw a small portion of the cuticle. (Use a prepared specimen.)

Can you suggest the use to the earthworm of such a covering?

G. Blood-vessels.

These are seen through the skin along the middle of the dorsal and ventral surfaces. (To observe the ventral vessel place the worm in a glass tube or on a glass plate.)

1. Do they extend the entire length of the body?
2. Observe the pulsation of the dorsal vessel. Is it regular?
3. In which direction does the pulsation move in your specimen?

4. Does the pulsation always move in the same direction?

H. Internal Structure. *Anatomy.*

1. In a thick cross-section of the body of the earth-worm observe, —
 - (a) the **body wall** ;
 - (b) the **alimentary canal**, the central digestive tube ;
 - (c) the **body cavity**, the space between the body wall and the alimentary canal.
2. The Body Wall. (Use a thin prepared cross-section.) Observe three layers of tissue in the body wall. These are, —
 - (a) the **epidermis**, a single outer layer of cells ;
 - (b) the **circular muscles**, long fibers (**muscle cells**) extending circularly around the body ;
 - (c) the **longitudinal muscles**. Notice that these fibers, cut crosswise, appear like small dots arranged in feather-form order.
3. The Setæ.
In the same section identify bristle-like structures projecting from the body wall (**setæ**). Notice the muscle strands.
4. The Alimentary Canal. (Use a specimen which has the dorsal body wall removed.)
 - a. Identify the body wall, body cavity and alimentary canal.
 - b. Does the alimentary canal extend the entire length of the body?
 - c. Observe the membranes (**septa**) which suspend the alimentary canal in the body cavity. How are the septa situated with reference to the somites?

- d.* Beginning at the anterior end identify the following modifications of the alimentary canal,—
- (1) the **pharynx**, a whitish muscular enlargement of the canal extending to the seventh somite ;
 - (2) the **oesophagus**, a thin-walled tube extending to the twelfth somite ; (It is usually partly covered by the thickened septa of this region.)
 - (3) the **crop**, an abrupt enlargement of the canal ;
 - (4) the **gizzard**, a thick-walled enlargement ;
(The crop and gizzard occupy about three somites.)
 - (5) the **stomach-intestine**, the remainder of the alimentary canal.

5. The Nerve Cord.

The **nerve cord** is a white thread-like structure lying under the alimentary canal.

- a.* What is its extent ?
- b.* How does it end anteriorly ? Look for the "**brains**" on the dorsal anterior surface of the pharynx.
- c.* Observe the **ganglia**, slight enlargements of the nerve cord. There is one in each somite.
- d.* Observe very small lateral branches of the nerve cord in each somite. (Dem.)

6. The Circulatory System.

- a.* Identify in the body cavity the two blood-vessels (**dorsal vessel** and **ventral vessel**) which you saw in the living worm.
- b.* Observe six pairs of large **lateral vessels** ("hearts") connecting the dorsal and ventral vessels in the region of the oesophagus.

I. Locomotion.

1. Identify the setæ on the ventral surface of a living earthworm. (If you cannot see them, feel for them.)
2. How many rows of setæ are there? How many setæ on each somite?
3. In locomotion what is the use of the setæ?
4. How is locomotion accomplished?
5. Can an earthworm crawl up a vertical surface? (Place earthworms in a deep glass dish and keep the sides of the dish wet. Devise other tests also.)

J. Burrowing.

Place an earthworm upon earth which has been slightly pressed down and observe its method of burrowing.

1. How is the burrow made?
2. How is the earthworm adapted to this work?
3. Does the earthworm avoid the light? (Place a small earthworm in a moistened tube one half of which has been covered with black paper. Repeat several times.)

K. Drawings, Diagrams and Models.

1. Draw the dorsal view of an earthworm.
2. Make a diagram of three somites of the ventral surface to show the position of the setæ.
3. Cut out a paper model of a cross-section of the earthworm. Color the model, using red for blood vessels and muscles, blue for nerves and epidermis, and yellow for the alimentary canal.
4. Cut out a paper model of a medium longitudinal section in the dorso-ventral plane showing the body wall, the septa and the alimentary canal, disregarding modifications.

5. Make a diagrammatic drawing of a cross-section of the earthworm (4 cm.).
6. Make a similar drawing to illustrate H 4.
7. Make a drawing to illustrate H 5.
8. Make a drawing to illustrate H 6.
9. Make a diagram of the circulatory system.

L. Suggestive Questions.

1. Why cannot earthworms survive drying ?
2. What becomes of earthworms in dry weather ?
3. What becomes of them in winter ?
4. How do earthworms enrich the soil ?
5. Do they injure plants or animals ?
6. What is the earthworm's protection from its enemies ?
7. Where are the new somites added as the earthworm grows ? (Compare on three worms the number of somites anterior to the girdle with those posterior to it.)
8. If an earthworm were obliged to live in water, what modifications in its make-up would be necessary ?
9. Why is the elongated type of body of the earthworm better adapted to differentiation and higher organization than the radiate type of the Hydra ?
10. What advantage is there in the double-tube plan of body of the earthworm over the single-tube plan of the Hydra ?

3. A MARINE ANNELID WORM.

A. The Body.

1. Identify the anterior and posterior ends.
2. How can you tell the ventral surface from the dorsal surface ?

3. Is the worm bi-laterally symmetrical?
4. How do the somites vary in size?
5. How does the most anterior part of the worm (**prostomium**) differ from the somites which follow it?
6. Where is the mouth located with reference to the prostomium?
7. Locate four small eye-spots on the dorsal surface of the prostomium.

B. The Appendages.

1. What is the general arrangement of the appendages?
2. Is any somite without its pair of appendages?
3. Why do the appendages vary in size?
4. Notice in the make-up of a single appendage, —
(a) a tuft of hair-like bristles (**setæ**);
(b) a fleshy part (**gill**).
5. Are the setæ nearer the dorsal or the ventral side of the worm?
6. Do you find any tentacles, or "feelers," at either end of the body?

C. Optical Anatomy.

In a small mounted specimen trace the alimentary canal through the transparent body wall distinguishing, —

- (a) the **pharynx**, an anterior thick-walled enlargement;
- (b) the **crop**, a thin-walled enlargement next posterior to pharynx;
- (c) the **stomach-intestine**, a thin-walled tube extending through the remainder of the body.

D. Suggestive Questions.

1. For what form of locomotion is this worm best fitted?
How?
2. On what kind of food does it probably live?
3. Can you tell by looking at a dead worm how it seizes
its food?
4. How would this worm need to be modified in order
to be adapted to the earthworm's habitat?

E. Draw, sketch or make diagrams to illustrate this study.

STUDY V. ECHINODERMATA. SPINY-SKINNED ANIMALS.

Central idea: Symmetry with relation to habitat and locomotion.

1. THE STARFISH.

A. Symmetry.

1. Identify a central region and five "arms" or **rays**.
2. Are there always five rays? (Examine several specimens.)
3. Are the rays always of the same size? Why?
4. Is the symmetry of the starfish more like that of the hydra or that of the earthworm?
5. What will you call this form of symmetry? (See p. 41, 7.)

B. Surfaces.

1. Identify the upper (**aboral**) and the lower (**oral**) surface. The aboral surface can be recognized by the presence of a wart-like disk (**madreporite**). On the oral surface is located the mouth surrounded by a membrane (**peristome**).
2. Identify the **ambulacral grooves** extending along each ray on the oral surface.
3. Observe that the shortest dimension of the animal is from the upper to the lower surface. Such an animal is said to be **flattened**. If the shortest dimension of an animal is from side to side, it is said to be **compressed**.

C. Exoskeleton.

An **exoskeleton** is any hard substance developed in or upon the skin of an animal.

1. Identify the small plates (**ossicles**) which make up the skeleton of the starfish. (Dem.)
2. Examine the hard projections (**spines**). What is their use?
3. How do the spines along the edges of the ambulacral grooves differ from the other spines? What is the reason for this difference?
4. Why is the skin between the ossicles so tough and leathery?
5. Identify among the spines on the aboral surface soft tapering structures (**aboral tentacles** or **dermal gills**), used in breathing. (These show much better if the specimen is under water.)
6. Observe a thread-like ridge along the middle of the groove. This indicates the position of a **radial nerve**.

D. Ambulacral Feet and Madreporite.

Identify tube-like projections (**ambulacral feet**) along the ambulacral groove.

1. How many longitudinal rows of feet do you find in each groove?
2. Are the feet in adjacent rows opposite or alternate? (Examine also a dried specimen from which the ambulacral feet have been removed.)
3. Observe the pinkish sensory spot at the distal end of the groove. This is called an "**eye-spot**."
4. What is the appearance of the madreporite under a lens?

How would you describe the exact location of the madreporite ?

E. Drawings.

1. A diagram of the aboral surface. (6 cm.)
2. A diagram of the oral surface. (6 cm.)
3. A drawing of a portion of the body wall to show the relation of the ossicles to the skin.
4. A diagram to show the arrangement of the ambulacral feet.
5. A careful drawing of the aboral surface.
6. A similar drawing of the oral surface.

2. THE SEA-URCHIN.

A. Compare a sea-urchin and a starfish with regard to the following points, —

- (1) the shape ;
- (2) the symmetry ;
- (3) the surfaces ;
- (4) the spines.

B. Exoskeleton.

Notice that in the sea-urchin the exoskeleton is composed of plates united in such a way as to form a nearly spherical shell. (Dem.)

1. Identify the areas of large perforated plates (**ambulacral plates**). To what in the starfish do these correspond with respect to position ?
2. Identify the areas of smaller **interambulacral** plates between the ambulacral areas.
3. How many sets of ambulacral and interambulacral areas are there ?

3. THE SEA-CUCUMBER.

A. Compare with the starfish and sea-urchin in regard to the following points, —

- (1) the shape ;
- (2) the symmetry ;
- (3) the surfaces ;
- (4) the exoskeleton. (Dem.)

B. Identify, —

- (1) the ambulacral feet ;
- (2) the tentacles around the mouth.

C. Suggestive Questions.

1. How do the habitats of the starfish, sea-urchin and sea-cucumber differ ?
2. Why are there no fresh-water representatives of this group ?
3. How did Louis Agassiz illustrate the way in which a starfish might theoretically have become changed into a sea-urchin ?
4. Why are starfish of interest to oyster fishermen ?
5. How does the starfish eat ?
6. What is the “**water-vascular system**” ?

4. THE DEVELOPMENT OF AN ECHINODERM.

A. Identify and draw the following stages in the development of a young starfish or sea-urchin, —

- (1) the **egg**, a single cell ;
- (2) the **two-celled stage** ;
- (3) the **four-celled stage** ;
- (4) the **eight-celled stage** ;

- (5) the **blastula**, a spherical mass of cells resembling a blackberry ; (It is really a hollow sphere.)
 - (6) the **gastrula**, a cup-shaped structure, formed as if one side of the blastula had been pushed in ;
 - (7) the **larva**, a transparent *bi-lateral* creature with several "arms," which swims about freely. (Dem.)
- The first six stages illustrate the development (**embryology**) of the many-celled animals (**metazoa**).

STUDY VI. ARTHROPODA. JOINT-FOOTED ANIMALS.

Central idea : Differentiation and homology.

1. THE CRAYFISH.

A. Habitat.

1. Where would you look for crayfish ?
2. How can you catch them ?
3. Where do they make burrows ? Why ?
4. How can you recognize the burrows ?

B. General Observations.

1. Compare the shape of the dorsal and ventral surfaces.
2. What is the color of the living crayfish ?
3. How is this color of any use to the crayfish ?
4. Identify two distinct regions of the body, — an anterior region (**cephalo-thorax**) and a flexible posterior region (**abdomen**).
5. In what ways are the differences between the anterior and posterior ends more marked than in the earthworm ?

C. The Shell. (Exoskeleton.)

1. Does the shell cover every part of the animal ?
2. How is the shell modified at the joints to permit movement ?

3. What is the advantage of such a shell to the crayfish?
4. What disadvantages has it?
5. The Carapace.
The shell over the dorsal and lateral surfaces of the cephalo-thorax is called the **carapace**.
 - a. Is it continuous with the shell on the ventral surface?
 - b. Observe the extension of the shell forward into a pen-like projection (**rostrum**).
 - c. Observe a transverse groove (**cervical groove**) between the head and the thorax.
6. The Abdominal Shell.
 - a. How many ring-like parts (**somite shells**) are there in the shell of the abdomen?
 - b. How are the somite shells arranged to permit the bending of the abdomen and still give protection?
 - c. Exactly where are the hinges between the movable somite shells?

D. Appendages of the Thorax.

The appendages of the thorax are called "**walking-legs**." The large pair are often called **chelipeds**.

1. How many pairs of walking-legs are there?
2. Which are provided with pinchers? (In numbering serial structures always begin with the anterior.)
3. What special uses have those which are provided with pinchers?
4. In walking, are the walking-legs used in regular order, *i.e.* in **coördination**?
5. Why do the chelipeds often vary in size? (Examine several specimens.)

E. Appendages of the Abdomen.

1. The Swimmerets.

The appendages of the abdomen are called **swimmerets**.

- a. How many pairs of swimmerets are there?
- b. Which somites are not provided with swimmerets?
- c. Observe that each swimmeret is made up of the following parts, —
 - (1) **protopod**, the stalk ;
 - (2) **exopod**, the outer branch ;
 - (3) **endopod**, the inner branch.
- d. What are the movements of the swimmerets?
(Watch crayfishes in water.)
- e. What are the uses of the swimmerets?
(Examine a crayfish which is carrying its eggs.)

2. The Caudal Fin.

The **caudal fin** is made up of the seventh somite (**telson**) and the swimmerets of the sixth somite.

- a. What is the shape of the caudal fin?
- b. What is its use? (Place a crayfish in water and watch it swim.)
- c. How is it used?
- d. How are the parts of the fin arranged?
- e. How is it adapted to its work?

F. Appendages for Taking Food.

There are three groups of appendages for taking food (**mouth parts**) situated between the chelipeds and the mouth. Examine them on living crayfishes and compare with mouth parts which have been removed from dead specimens. First find the mouth and then identify, —

- (1) the **maxillipeds**, three pairs of finger-like appendages attached just in front of the chelipeds; (Lift up the large outer third pair to see the first and second pairs.)
- (2) the **maxillæ**, two pairs of very small, thin, plate-like appendages attached in front of the maxillipeds; (They lie against the mandibles.)
- (3) the **mandibles**, thick hard jaws, one on each side of the mouth.
 - a. What is the direction of their movement, sidewise or lengthwise the body?
 - b. Observe a three-jointed finger (**palp**) on each mandible.

G. The Sense Organs.

1. The **Antennæ**. (The long "feelers.")
 - a. Watch crayfishes which have not been disturbed and observe the use and movements of the antennæ.
 - b. What is their "reach" as compared with the other appendages?
 - c. How are they made more flexible than the other appendages?
2. The **Antennules**. (The short "feelers.")
 - a. How many pairs of antennules are there?
3. The **Eyes**.
 - a. Observe that the eye is mounted on a movable stalk.
 - b. Of what advantage is the stalk?
 - c. What protection from injury have the eyes? (Touch them gently.)
 - d. The **cornea**, the outer covering of the eye. Observe the division of the cornea into small

“squares” (**facets**). Sketch a group of six facets. (Use a mounted preparation, l.p.)

A facet is the cornea of a single simple eye. The eye of the crayfish being made up of many hundred such eyes is said to be **compound**.

4. The Ear-sacs. (Dem.)

These are small sacs located on the dorsal side of the basal segment of the antennules.

H. The Respiratory System.

Respiration is carried on by means of **gills**. These are white feathery structures located under the carapace and arranged in two groups, one on each side of the thorax, in a special cavity (**gill-chamber**).

1. The Gill-chamber. (Examine a specimen from which has been removed that part of the carapace which is over the gills.)

a. Observe how far the gill-chamber extends dorsally, ventrally, anteriorly and posteriorly.

b. What is the character of the inner wall?

2. The Gills.

a. Observe the arrangement of the gills in sets. (Lift up the outer gill.)

b. Observe that the outer gill in each set is attached to the basal segment of an appendage.

What advantage is thus gained?

c. Are the gills external or internal structures?

3. The Paddle. (Dem.)

This is a thin doubly-curved plate at the anterior end of the gill-chamber, belonging to the second maxilla. It causes a current of water through the gill-chamber.

I. A Study of Muscles. (Dem.)

The abdomen of the crayfish in swimming is moved by two sets of muscles, the **extensors** and the **flexors**. The extensor muscles straighten the abdomen, while the flexors bend it.

1. Are the flexors located on the dorsal or the ventral side of the abdomen?
2. Where are the extensors located?
3. Where must the muscles be attached anteriorly?
4. Which are the stronger, the extensors or the flexors? Why?

In the same manner locate the position of the muscles which operate the pinchers of the chelipeds. They are called **abductor** and **adductor** muscles.

5. Why are these muscles so named?
6. Do these muscles differ in size? Why?

J. Drawings.

1. Draw the crayfish from the dorsal view, with the appendages and caudal fin outspread.
2. Draw one of each of the following appendages,—
 - (a) the third maxilliped with its gill;
 - (b) the second maxilla with the paddle;
 - (c) the mandible;
 - (d) the cheliped with its gill;
 - (e) the fifth walking-leg;
 - (f) the third swimmeret.

K. Experimental Studies.

NOTE. — These experiments require careful and patient study. Do not be satisfied with one trial. Great care must be taken to avoid frightening or tiring out the animals. Try to secure conditions as nearly natural as possible. If the crayfish fails to respond to your tests, make a record of it. These may be called *negative results* and are often as important as the positive results which you usually expect.

1. Feeding.

Tempt a crayfish to eat. (It is difficult to get the crayfish to eat in captivity. Try small bits of liver or fish.)

- a. What appendages are used in handling the food and in passing it to the mouth?
- b. What, if any, appendages are used in breaking or cutting the food?
- c. Describe the process of feeding.
- d. Does the crayfish like some kinds of food better than others?
- e. Can the crayfish tell its food from other substances?

What is the natural food of the crayfish?

2. The Sense of Feeling. (Touch.)

- a. With a bristle test the sense of feeling in various parts of the body,—the shell, appendages, eyes, “feelers,” setæ, etc. What parts of the body are most sensitive?
- b. Observe the movements of the crayfish with a view to discovering the use of the antennæ. Record observations.
- c. How are the antennæ carried when the crayfish is at rest? When the crayfish is in motion?
- d. What work can you suggest for the antennules that cannot be done as well by the antennæ?

3. The Sense of Smell.

- a. Test the sense of smell by using some pungent substance. (Dem.)
- b. Where is the sense of smell located?

4. The Sense of Taste.

- a. Test for this sense by placing some sour or bitter substance on the mouth parts. (Dem.)

5. Sight.

a. Keeness of sight. Watch the movements of a crayfish. Does it see objects in its way and turn aside before touching them? Invent various ways of testing the keeness of sight.

b. Range of vision.

(1) What is the extent of the crayfish's range of vision? (The crayfish's eye can see you wherever you can see the crayfish's eye.)

(2) Can the crayfish see what it is eating?

(3) Can it tell where it is going when swimming?

6. Hearing.

a. Test the hearing of the crayfish. (Record results.)

7. Circulation of water for Respiration. (Dem.)

a. Place a crayfish in a shallow dish of water. With a pipette inject a drop of ink into the water near the ventral edge of the carapace. Is the ink drawn under the carapace into the gill-chamber or driven away? Place another drop between the chelipeds near the mouth. What is the result?

b. What is the course of the water through the gill-chamber?

c. What causes the water to flow through the gill-chamber?

d. How are small objects kept out of the gill-chamber?

e. How can the crayfish live out of water for a considerable length of time as it often does?

L. Table of Appendages.

1. Prepare a table similar to the model below. Fill out the table with the proper entries in each column for all the appendages in order, beginning with the antennules.

REGION OF THE BODY.	NO. OF APPEN.	NO. OF SOMITE.	NAME OF APPENDAGE.	PARTS REPRESENTED IN EACH APPENDAGE.				USE.
				PROTOP.	EXOP.	ENDOP.	SPECIAL.	

Number the appendages in order from the antennules.
Under "Special" include gills, paddle, palps, etc.

2. Questions on the Table.
- How are the appendages **homologous** in structure?
("Homologous" means likeness in general plan of structure.)
 - Which appendages are the simplest in structure?
 - Which are the most highly specialized?
 - According to their uses how many groups of appendages are there?
 - According to their structure how many groups are there?
 - Savigny formulated the law, "*Every somite should have a pair of appendages.*"
 - What is the evidence of the truth of this law as shown in the crayfish?
 - What evidence of its failure is there?
 - Supposing it to be true, how many somites are there in the body of the crayfish?
How many in the head? How many

in the thorax? How many in the abdomen?

M. Suggestive Questions.

1. What kind of localities do crayfish prefer?
2. Why are there no crayfish in "granite New England"?
3. Why cannot crayfish readily catch live animals for food?
4. Why does the crayfish sometimes leave the streams?
5. Is the crayfish edible?
6. How are they caught by fishermen?
7. When is the breeding season?
8. How do they care for their eggs and young?
9. Turn a crayfish over on its back. Is there coördination in its movements to right itself?
10. Compare the position of the mouth in the earthworm, the marine worm and the crayfish. What relation does this change of position have to the development of a head?
11. Compare the earthworm and the crayfish in respect to the following characteristics, placing the answers in parallel columns,—
 - (a) segmentation;
 - (b) exoskeleton;
 - (c) appendages;
 - (d) regions of the body.

2. THE CRAB.

A. The Regions of the Body.

1. Identify cephalo-thorax and abdomen.
2. How does the width of the cephalo-thorax compare with its antero-posterior dimension?

3. How does the size of the cephalo-thorax compare with that of the abdomen?
4. What is the natural position of the abdomen with reference to the cephalo-thorax?
5. How does the number of somites in the abdomen of the crab compare with the number in the abdomen of the crayfish?
6. Is the crab compressed or flattened?
7. Sketches.
 - a. Make an outline sketch of the dorsal surface of the crab, omitting the appendages.
 - b. Make a similar sketch of the ventral surface.

B. Cephalic Appendages.

1. Identify the antennæ, the eyes and the "mouth parts." Indicate their position in the sketch for **A 7 b**.

C. Thoracic Appendages.

1. Identify the pinchers and the walking-legs. Indicate their position in the sketch for **A 7 b**.
2. How does the fifth pair of thoracic appendages differ in different species of crabs? Why?

D. Abdominal Appendages.

1. Identify the swimmerets.
2. Are all the somites of the abdomen provided with appendages?
What reasons can you suggest for the absence of a caudal fin?

E. Suggestive Questions.

1. What is the habitat of the crabs you have studied?

2. Do crabs swim backwards? (You can answer this question about living crabs from the dead specimens.)
3. What changes would have to take place in the crayfish in order for it to become a crab?
4. What changes would be necessary in the appendages? Which is the "higher form," the crab or the crayfish?

3. THE PILL-BUG.

1. Where is this animal found? (Dem.)
2. Describe, —
 - (a) the color;
 - (b) the shape.
3. How many somites are there in the entire body?
4. How can you distinguish cephalo-thorax from abdomen?
5. Are any of the appendages provided with pinchers?
6. Are the eyes on stalks?
7. Identify the antennæ.
8. Identify the plate-like gills on the abdomen.
Why is this animal included in the same class with the crayfish?
Do *you* think the pill-bug is a simpler or a more highly organized animal than the crayfish?
What inappropriateness in the word "bug" when applied to this animal?

4. THE FAIRY SHRIMP. *Branchipus*.

A. The Living Shrimp.

1. Habitat.
 - a. What is its habitat?
 - b. At what time of year is it found?
 - c. How does it pass the winter?
 - d. Where is it in midsummer?

2. What is peculiar about its position while swimming?
3. Why is "fairy shrimp" an appropriate name?
4. Is it quick to see? (Test for this.)
5. Is it quick to feel? (Test by touching lightly.)
6. Which end is the more sensitive?
7. What is the probable food of the fairy shrimp?
8. Note the "wave of motion" produced by the gills.
Is it from the anterior to the posterior or vice versa?
9. If the gills are swimming organs, in which direction ought the wave of motion to be to make the shrimp go forward?
10. Can a shrimp remain motionless? In other words, can it "stand still"?
11. Do the gills ever stop moving?
12. By just what means does the shrimp swim?
13. What is peculiar about the packet of eggs on the female?

B. Body Regions.

1. Identify head, thorax and abdomen.
2. Are these regions more distinct than in the crayfish?
3. Are these crustaceans clad in a "crust"-like shell?
4. Which of the body regions are plainly divided into somites? (What is the case in the crayfish?)
5. Identify the alimentary canal through the transparent body wall. It is ordinarily filled with food and can be seen very distinctly.
6. Identify the long heart which lies in the thorax dorsal to the alimentary canal. It is usually quite transparent.

C. Appendages, etc.

1. Of the Head : —
 - a. How many pairs of antennæ are there?

Why are the antennæ so small in the shrimp and so large in the crayfish? (Remember that the shrimp and the crayfish swim in opposite directions.)

- b.* Identify the prominent stalked eyes.
 - c.* Identify also a single smaller median eye.
 - d.* Where is the mouth located?
 - e.* Identify a large pair of jaw-like organs. (These are modified antennæ and are present only on the male shrimp.)
2. Of the Thorax : —
- a.* Identify the prominent gills.
 - b.* How many pairs of gills are there?
 - c.* What two uses have these gills?
3. Of the Abdomen : —
- a.* Are any swimmerets present?
 - b.* What is peculiar to the appendages of the last somite? (1.) What is the probable use of these appendages?
 - c.* Notice the packet of eggs attached to the female shrimp.
 - d.* Is the packet of eggs situated dorsally or ventrally?
 - e.* Is the packet of eggs carried above or below the shrimp when it swims?
- Why does not the shrimp have a caudal fin?

D. Make Sketches to illustrate this study.

5. THE LOCUST. “*Grasshopper.*”

A. Habitat.

1. Where do grasshoppers live?
2. Do they like sunny or shady fields?

B. General Observations.

1. Observe that the "shell" of the grasshopper is much lighter and more flexible than the shell of the crayfish. Why is this necessary?
2. What sort of a background will make the grasshopper difficult to be seen?
3. Identify three distinct regions of the body, — head, thorax and abdomen.
4. Why is the grasshopper said to have three regions to the body and the crayfish only two regions?
As compared with the crayfish, in which of the body regions has there been the greatest differentiation?

C. The Head and its Appendages.

1. What is the shape of the head? (Make sketches.)
2. Is there a "neck"?
3. In what direction is the head movable?
What advantage is gained by its being movable in this direction?
4. The Eyes.
 - a. What is their position?
 - b. Are they "compound"?
 - c. **Ocelli.** These are three very small, **simple** (single) eyes. One is situated in the middle of the forehead and one just above each antenna.
 - d. Compare the grasshopper's range of vision with that of the crayfish.
 - e. Make a sketch to show the position of the eyes.
5. The Antennæ.
 - a. Observe their position, shape and segmentation.
 - b. Are they movable?
 - c. Compare in structure with those of the crayfish.

6. Mouth parts.

- a.* **Labrum**, the upper lip. What is its shape? Is it movable?
- b.* **Labium**, the lower lip. Compare it with the labrum. Observe the three-jointed **palps**.
- c.* **Mandibles**, strong, dark jaws situated under the labrum. Observe their relation to the mouth and notice the cutting teeth on them.
- d* **Maxillæ**.

These are situated just in front of the labium and are each composed of three parts ; a cutting tooth, a spoon and a five-jointed palp.

What is the function of each of the mouth parts?
What are the palps for?

In what direction with relation to the body must the grasshopper hold its food in order to chew or to bite it?

Can you think of any reason for the notches in the lips?

D. The Thorax and its Appendages.

1. Observe the division of the thorax into three segments, each of which has a pair of legs. The segments are named in order from the anterior end **prothorax**, **mesothorax** and **metathorax**.
2. The Legs.
 - a.* Observe that the first and second pairs of legs have a lateral direction with relation to the body, while the third pair extend posteriorly.
 - b.* Observe also the difference in size between the third, and the first and second pairs of legs.
 - c.* Why is the third pair of legs different from the other two pairs?

Why could not the third pair extend in the same direction as the other two pairs ?

- d. Observe these *principal* segments in the leg, —
- (1) the **Femur**, the swollen more proximal segment ;
 - (2) the **Tibia**, the slender middle segment ;
 - (3) the **Tarsus**, the foot.
- e. Observe the joints of the tarsus.
- (1) Of what advantage are they ?
 - (2) What are the **hooks** and **pads** for ?

3. The Wings.

- a. What is the resting position of the wings ?
- b. How are they related to each other with regard to their position while at rest ? How are they related when outspread ?

The straight ridge-like arrangement of the wings when at rest gives the name *Orthoptera* (straight-wings) to the order of insects to which the grasshopper belongs.

- c. Compare the **fore-** and **hind-wings** with respect to,—
- (1) their shape ;
 - (2) their size ;
 - (3) their thickness ;
 - (4) their folding.
- d. The **Veins**, thread-like thickenings of the wings.
- (1) What is their arrangement ?
 - (2) In which part of the wings are they strongest ? Why ?

Why are the wings attached so near to the dorsal edge of the body ?

Do the fore- and hind-wings differ in function ?

Give reason for your answer.

Why is the thorax the strongest part of the body ?

E. The Abdomen.

1. How many somites are there in the abdomen?
(The first somite and the last two are incomplete.)
2. Spiracles.
The **spiracles** are the openings of breathing tubes (**tracheæ**). They are very small and are situated one on each side of the first eight somites. There are also two pairs of spiracles on the thorax.
3. Ovipositors.
The **ovipositors** are two pairs of wedge-shaped structures on the end of the abdomen of the female grasshopper. They are used for depositing the eggs in the ground.
4. Ear Sacs.
Look for these under the wings on the first abdominal somite.
5. Sketch the abdomen, side view.
6. If live grasshoppers are at hand, find out how they breathe by watching the movements of the abdomen.

F. Drawings.

1. Draw the grasshopper from a side view with the legs and wings arranged in their natural position.
2. Draw the head from the front view.
3. Draw the hind-wing outspread.

G. Suggestive Questions.

1. What plants do grasshoppers like best?
2. How are grasshoppers sometimes of great economic importance?
3. Why are they so much more plentiful some years than others?

4. Why do they sometimes "migrate"?
5. What enables the grasshopper to sustain itself for so long a time in the air when migrating?
6. What becomes of the grasshoppers in the fall?
7. How is next season's supply of grasshoppers provided for?
8. Can you drown a grasshopper by holding its head under water?
9. What modes of locomotion are optional with the grasshopper?
10. Can a grasshopper alight where it wants to when it jumps?

6. THE METAMORPHOSIS OF A MOTH. *Cecropia.*

A. The Cocoon.

The **cocoon** is a case enclosing the developing insect.

1. Where do you find these cocoons out of doors?
2. When is the best time to collect them?
3. How would you recognize them?
4. How can you tell whether the insect inside is alive?

B. The Pupa. (Use preserved material.)

The **pupa** is the developing insect found inside the cocoon.

1. What is its color?
2. Its shape?
3. Identify, —
 - (a) the head, thorax and abdomen;
 - (b) the rudimentary wings;
 - (c) the mouth parts.

C. The Imago. "Moth."

The **imago** is the adult form and develops directly from the pupa.

1. How does the moth get out of the cocoon?
2. At what season of the year does it emerge?
3. What is the appearance of the wings when it first emerges?
4. What changes does the moth undergo in the course of a few hours? Why?
5. Identify the same three regions of the body as in the pupa.
6. How many wings has the moth?
7. Are the mouth parts adapted for "biting" or for "sucking"?
8. What is peculiar about the appearance of the antennæ?
9. Does the imago grow?
What is the natural food of the moth?

D. Eggs. (Dem.)

The **egg** is the first stage in the development of the moth.

1. Observe the shape and the color of the eggs.
2. Are they deposited by the moth singly or in groups?
3. Where does the moth naturally deposit its eggs?
Why?
4. How long does the moth live after depositing its eggs?

E. The Larva. "Caterpillar."

The **larva** is the second stage of the moth and develops directly from the egg.

1. At what season of the year do you find caterpillars most abundant?
2. What is their food?
3. How many regions can you distinguish in the body of the caterpillar?

4. Is the larva more like the earthworm or the crayfish in appearance? Why?
5. How many legs has the larva?
6. Are all the legs of the same kind?

F. Drawings.

1. Draw each stage, natural size.

G. Suggestive Questions.

1. In what stage does the moth grow the most?
2. In what stage does it cause the most damage?
3. Do butterflies make cocoons?
4. Do all insects have a metamorphosis?

7. THE METAMORPHOSIS OF THE MOSQUITO.

A. Eggs. The first stage.

1. Observe the arrangement of a packet of eggs.
2. What is the shape of a single egg?
3. Can you wet them by putting them under water?
4. Can you make out the "trap door," on the under side of the egg, through which the young mosquito hatches into the water?
5. Draw.

B. Larva. The second stage.

1. Alive in a jar of water.
 - a. Why are they called "wigglers"?
 - b. What position do they take when at rest?
 - c. Must they wiggle to reach the surface of the water, or do they rise to the surface like a cork?
 - d. Must they wiggle to reach the bottom, or do they sink without exertion like a heavy chip?
Are they lighter or heavier than the water in which they live?

Why do they come to the surface?

e. Can they see? (Test to find out.)

f. How rapidly do they grow? (Observe for several days.)

2. Under l. or l.p. (Use mounted preparation.)

a. Identify a distinct head, thorax and abdomen.

b. The Head. Identify, —

(1) the **eyes**; (Are they compound or single?)

(2) the **antennæ**;

(3) the **vibratile organs**; (These are short and bushy for sweeping microscopic food into the mouth.)

(4) the **mouth**.

c. The Thorax. Ascertain whether there are to be seen, —

(1) any external legs;

(2) any legs folded up inside of the transparent body wall;

(3) any wings.

d. The Abdomen. Make out, —

(1) the number of somites;

(2) the **respiratory tube**, branching off near the end of the abdomen;

(3) the posterior opening of the alimentary canal.

e. Draw a larva.

C. Pupa. The third stage.

1. Alive in a jar of water.

a. How does the shape of the pupa differ from that of the larva?

b. How does the position of the pupa in the water differ from that of the larva in water?

- c. Is a pupa as lively as a larva?
2. Under l. or l.p. (Use mounted preparation.)
- a. Can you distinguish head, thorax and abdomen?
- b. Notice the two horn-shaped breathing tubes.
- c. Is the larval respiratory tube still present?
- What is the reason for the extraordinary change in the position of the pupa in water from that of the larva?
3. Draw a pupa.

D. Imago. The fourth stage. (Use preserved specimens.)

1. Can a mosquito bite? (Look for jaws.)
2. Can a mosquito sting? (Look for a stinger.)
3. What does a mosquito do when we say it "bites" or "stings"?

What is the natural food of mosquitoes?

4. How many wings does a mosquito have?
5. How are the wings ornamented?
6. Is your specimen a male or a female? (The male has large bushy antennæ.)

How does a mosquito "sing"?

Where are mosquitoes most abundant? Why?

How may they be kept in check?

What is the probable relation between mosquitoes and malaria?

8. AN EXERCISE IN IDENTIFICATION AND CLASSIFICATION.

Use the table on page 65 for finding out to which order each insect belongs.

Identification Table.¹

A. Jaw-like mouth parts for biting.

B. Two pairs of wings unlike in structure.

C. Outer wings sheath-like and meeting in a straight line; under wings folding in two ways, **Coleoptera** (Sheath-wings).

CC. Outer wings leathery and meeting in a straight ridge; under wings folding lengthwise like a fan,

Orthoptera (Straight-wings).

BB. Two pairs of wings alike in structure.

C. With very many "nerves" in the wings,

Neuroptera (Nerve-wings).

CC. With few "nerves" in the wings,

Hymenoptera (Membrane-wings).

AA. Tube-like mouth parts for sucking.

B. Two pairs of wings.

C. Wings covered with powdery scales,

Lepidoptera (Scale-wings).

CC. Wings not covered with scales.

D. Upper wings of uniform texture, with one wing crossing the other on the back, **Homoptera** (Similar-wings).

DD. Wings plainly of two different textures, with one wing crossing the other on the back, **Heteroptera** (Dissimilar-wings).

BB. One pair of wings.

Diptera (Two-wings).

¹ The classification here presented is far from complete, but will serve for general practice in using identification tables.

Suggestive Questions.

1. With which pair of wings does a coleopter fly?
2. Why cannot a coleopter fold its wings like a fan?
3. Why does not the orthopter fold its wings as a coleopter does?
4. Which is better fitted for rapid flight, the coleopter or the neuropter?
5. Why does the neuropter have larger eyes than the coleopter?
6. Which is the steadier flyer, the lepidopter or the hymenopter? Why?
7. What orders of insects have wings that cross on the back?
8. Are there any traces of a second pair of wings on the dipter?
9. How can a house-fly walk up a window pane and not slip?
10. Etc.¹

Common Representatives of the Foregoing Orders.

1. Coleoptera — beetles.
2. Orthoptera — grasshoppers, etc.
3. Neuroptera — dragon-flies, etc.
4. Hymenoptera — bees, etc.
5. Lepidoptera — butterflies and moths.
6. Homoptera — cicadas, tree-hoppers, etc.
7. Heteroptera — true bugs.
8. Diptera — flies, etc.

¹ *Invent* other questions similar to the above that will apply especially to the insects you have at hand to study. It is often more of an accomplishment to ask the right question than to answer it and you should keep in practice.

9. A COMPARATIVE REVIEW OF THE ARTHROPODA.

Prepare a table similar to the one indicated below. Place the name of the animal studied at the head of the column and fill in your answers below these headings.

NUMBER OF QUESTION.	CRAYFISH.	CRAB.	PILL-BUG.	FAIRY SHRIMP.	LOCUST.	MOTH.	MOSQUITO.	SPIDER.	MILLIPED.	ETC.

1. What method of locomotion does the animal use?
2. How many pairs of legs does the animal have?
3. What are the number and kind of eyes?
4. How many antennæ are there?
5. Where are the eggs deposited?
6. What is the animal's natural habitat?
7. What is its natural food?
8. In what manner does the animal feed itself?
9. How does the developing animal solve the problem of a growing body encased in an exoskeleton that does not grow?

STUDY VII. MOLLUSCA. SOFT-BODIED ANIMALS.

Central idea : The effect of a protective skeleton.

1. THE FRESH-WATER CLAM.

A. Habitat. (Dem.)

1. Where do these animals live ?
2. Do you find it necessary to search over a large area in order to find a large number of clams ?
3. What marks in the mud show that clams are present ?

B. General Observations.

1. Show by sketches the outline of the clam as seen from above and from the side.
2. Identify, —
 - (a) the broad margin (**dorsal margin**) and the opposite sharp edge (**ventral margin**) ;
 - (b) the **umbones**, a pair of elevations on the dorsal margin, usually nearer the anterior than the posterior end ;
 - (c) the **hinge-ligament** between and extending back of the umbones.
3. Draw the dorsal outline of the clam and indicate right, left, anterior, posterior, umbones and hinge-ligament. (In this and all subsequent drawings of the clam have the anterior end point toward the top of the paper.)

C. The Shell. Exoskeleton.

Each of the two parts of which the shell is composed is called a **valve**.

1. How would you name these valves to distinguish one from the other?
2. What is the function of the hinge-ligament? (Press the opened valves together.)
3. Structure of the shell. (Dem.)
 - a. Identify in order, —
 - (1) the **external coating**;
 - (2) the "**chalky**" **portion**;
 - (3) the **pearly portion**.
 - b. Does the external coating cover the entire shell?
 - c. Show by a sketch how the layers in the chalky and pearly portions are arranged.
 - d. As the clam grows, where are the new layers of shell added?
4. Composition of the shell. (Examine a burnt shell.)
 - a. What is the appearance of the part that remains after burning?
 - b. Has the animal matter or the mineral matter been removed by burning?
 - c. Test the burnt shell by dropping it into a bottle of acid. What action takes place? What remains after the action has ceased?
 - d. What mineral will give the same action if treated with acid?

D. Outer Surface of the Shell.

1. **Lines of growth**, concentric markings around the umbones.

What causes these lines?

2. Draw the right valve.

E. Inner Surface of the Shell.

1. The **hinge-teeth**, irregular or blade-like projections near the dorsal margin. Of these the more anterior are somewhat conical in shape and are called **cardinal teeth** while the more posterior are blade-like and are called **lateral teeth**.
 - a. Compare the "teeth" of the right with those of the left valve.
 - b. What is the function of the hinge-teeth?
2. The **anterior** and **posterior adductor muscle scars**. These are markings near the dorsal margin.
3. The **pallial line**. This extends from one muscle scar to the other.
4. Draw the inner surface of the two valves, arranging them so that their dorsal margins are next to each other.

F. The Clam in the Open Shell.

1. The **mantle lobe**, a flap covering the side of the body.
 - a. Determine whether it is the right or left lobe.
 - b. Observe its thickened margin.
 - c. What is the relation of this margin to the pallial line?
2. The **anterior** and **posterior adductor muscles**.
 - a. What is their relation to the muscle scars of the shell?
 - b. What is the function of these muscles?
3. The **siphons**, openings on the posterior end of the clam marked by a fringe of short, dark tentacles. (Dem.)

G. Structures in the Mantle Cavity.

The **mantle cavity** is the space between the mantle lobes.

1. The soft **body** located in the dorsal region.
2. The **foot**, a firm muscular structure on the ventral edge of the body.
3. The **gills**, large flap-like membranes on either side in the posterior portion of the cavity.
4. The **palps**, small flap-like structures at the anterior part of the body on each side of the mouth.
5. Identify the **inhalent siphon** which leads into the mantle cavity. The other, more dorsal opening is the **exhalent siphon**.
6. Make a diagram showing the clam in cross-section,—
(a) in the region of the umbones ;
(b) in the region back of the umbones.
7. Examine a prepared specimen of a portion of a gill.
(h.p.) Sketch.
8. Test the circulation of water in the live clam by placing a drop of ink in the water near the siphons.
(Dem.)
9. The gills of the clam are often distorted by the presence of **egg masses**.

H. Suggestive Questions.

1. Just how does a clam use its foot for locomotion?
(Observe live clams in the laboratory.)
2. What is the position of the clam in the mud?
Why?
3. Why does an oyster have two unlike valves?
4. How can an animal so well protected by a shell as the clam or oyster be eaten by the starfish?
5. What is a "mussel"?
6. What effect, in the course of long evolution, has the heavy protective shell had upon the clam?

2. THE SNAIL.

A. General Observations.

1. Watch the snail and observe its actions.
2. What is its form of symmetry?
3. What means of protection has it? (Disturb it gently.)

B. The Shell.

1. What fitness is there in the term "univalve"?
2. Ascertain the names of the different parts of the shell by comparing them with a diagram. (Dem.)
3. Is the spiral right handed or left handed? (Hold the shell with the aperture toward you and the spire pointing up.)
4. Do all snails possess shells? (Dem.)

C. Locomotion.

1. Identify the part (**foot**) by means of which the snail creeps.
2. Can the snail creep backward as well as forward?
3. Can it climb up the side of the aquarium while under water? While out of water?
4. Can it move on the surface of the water?
5. In what manner does it carry its shell when moving?
6. Sketch.

D. Sense Organs.

1. Identify the tentacles.
2. How many are there?
3. Identify the eyes.
4. Indicate these structures in your sketch.

E. Geotaxis. The movements of animals or plants with reference to gravity is termed **geotaxis**. (Dem.)

Place a slug ("a snail without a shell") in a horizontal position on a glass plate, being careful that the plate is at right angles to the light.

1. Observe and record by sketches the position of the snail at the end of 5, 10 and 15 minutes.
2. Is the snail influenced in its movements by gravity?

F. Phototaxis. The movements of animals or plants with reference to light is called **phototaxis**.

Have the glass plate used in **E** now stand with the edge toward the light. Place the snail in a vertical position.

1. Observe and record by sketches the position of the snail at the end of 5, 10 and 15 minutes.
2. Is the snail affected by light? How do you know?

G. Eggs.

These are often found in masses on the side of the aquarium.

1. Identify them.
2. Examine with l. and l.p.

3. THE SQUID.

A. General Observations.

Identify, —

- (1) the **body**;
- (2) the **head**;
- (3) the **eyes**;
- (4) the **tentacles**;
- (5) the **neck**, that part which allows the head to move;
- (6) the **mantle**, fitting like a collar around the neck;
- (7) the **siphon tube**, showing between the collar and the neck on the ventral side;

- (8) the **terminal fin**;
- (9) the **mouth**, surrounded by the tentacles;
- (10) the **organs of smell**, folds of skin just posterior to the eyes;
- (11) the **chromatophores**, blotches of color all over the body;
- (12) the **mantle-cavity**, "down the neck" inside the collar;
- (13) the **pen**. (The dorsal median projection on the collar is the point of the "pen" which is embedded in the body wall of the squid.)

B. External Details.

1. The Tentacles.

- a. How many tentacles are there?
- b. Are the tentacles all of the same kind?
- c. What is the arrangement of the "suckers" on the tentacles?

Why do the tentacles surround the mouth?

2. The Eyes.

- a. Can a squid close its eyes?
- b. Can a squid see where it is going? (It usually swims backward.)

3. The Terminal Fin.

- a. Cut out of paper a pattern of the terminal fin.
- b. In what position is it attached to the body?
What is the advantage to the squid in having this shape of terminal fin?
Is the terminal fin used in locomotion?

C. Internal Details.

Identify, using under water a prepared specimen showing the mantle-cavity opened, —

- (1) the outer opening of the siphon-tube ;
- (2) the inner opening of the siphon-tube ; (Pass a tipped bristle through the siphon-tube and make sure that you understand how the water can come in around the collar and escape through the siphon-tube.)
- (3) the **retractor muscles**, two large fleshy ridges attached to the siphon-tube near one end ;
- (4) the **alimentary canal**; (Its posterior end may be seen near the inner opening of the siphon-tube through which the waste products of digestion pass into the water.)
- (5) the **ink sac**, lying between the alimentary canal and the body wall and probably still containing traces of black "ink" ;
- (6) the **gills**, two large feathery breathing organs.

D. Sketches.

1. A lateral view (10 cm.).
2. A prepared specimen showing mantle-cavity opened (10 cm.).

E. Suggestive Questions.

1. Why does the squid take water into its mantle-cavity and expel it violently through the siphon-tube ?
2. How would you need to modify a clam theoretically to make a squid out of it ?
3. Can you see any reason why the nervous system of the squid should be better developed than that of the clam ?
4. What is the probable use of the pen ?
5. What is the use of the "ink" ?

STUDY VIII. VERTEBRATA.

Central idea: The advantage of the "backbone" plan of structure.

1. THE GOLDFISH AND PERCH.

A. General Observations.

1. What kind of symmetry does this fish possess?
2. Show by means of sketches the outline of the body of the fish as seen from above and from the side.
3. Is the fish compressed or flattened?
4. Of what advantage to the fish is a body of this shape?
5. Of what advantage is it to the fish that the head is not movable independently of the body?
6. Count the number of paddle or fan-like appendages (**fins**). Observe that some of the fins are median and that others are in pairs.

B. Locomotion.

1. Is the fish an active or a sluggish animal?
2. Does it ever remain perfectly quiet?
3. Can it remain stationary without using its fins?
4. Can it go backward as well as forward?
5. Can it raise and lower itself in the water?
6. Identify and *determine the use* of the following fins,—
(a) the **dorsal fin**, the median fin on the dorsal surface;
(b) the **caudal fin**, the fin forming the tail;

- (c) the **anal fin**, the median fin on the ventral side just anterior to the tail;
- (d) the **pectoral fins**, the more anterior of the paired fins;
- (e) the **pelvic fins**, the more posterior of the paired fins.

7. Structure of the fins.

- a. Each fin is simply a fold of skin supported by numerous bony or cartilaginous **rays**. Identify the rays in each fin.

What advantage is there to the fish in having the fin constructed in this manner?

Why does the dorsal fin have hard bony rays while the caudal fin has soft cartilaginous ones?

- b. Can the fins be closed?

If so, is any advantage gained thereby?

C. Sense Organs.

1. Do *you* think there is any definite purpose in the movements of the fish? (Give your reasons.)
2. Identify the following Sense Organs, —
 - (a) the **nostrils**, small openings in front of the eyes;
 - (b) the **eyes**;
 - (c) the "**lateral line**" indicating the position of sense organs supposed to help the fish in balancing itself.
3. The Nostrils.
 - a. How many are there?
 - b. Do they open into the mouth? (Dem.)
 - c. Are they used in breathing?
 - d. Can a fish smell? (Dem.) Give evidence.
4. The Eyes.
 - a. Why are they located on the sides of the head?

- b.* How great a "range of vision" has the fish?
(Refer to crayfish study, K 5 *b.*)
 - c.* Show by means of a sketch the iris and the pupil.
 - d.* How many eyelids are there?
 - e.* Can a fish close its eyes?
 - f.* Does the fish notice things?
 - g.* What means of protection have the eyes? (Look at skeleton of a fish.)
 - h.* What is the meaning of the unusual flattened condition of the eye?
5. The Ears. The **ears** are small sacs embedded in the skull. Each sac is lined with sensory hairs and contains a small stone (**otolith**). This is "anatomical evidence" that a fish can hear. Can you give any other evidence that the fish actually does hear?

D. The Mouth.

1. Observe how wide the mouth can be opened.
2. Observe that the bones of the upper jaw are movable, allowing it to act as a "lip." Show by sketches the relation of these bones to each other.
3. Has the fish teeth?
4. How does the fish seize its food?
5. Does the fish chew its food?
6. The Tongue.
 - a.* What is the shape of the tongue?
 - b.* Can the fish taste? (Place bits of brown paper and bits of fish food in the jar with the fish.)

E. Respiration.

1. Identify the **operculum**, a flap with a bony framework on each side of head. It covers and protects the gills.

2. Identify the gills. (Dem.)
 - a. Observe that each gill consists of a row of fringes (**gill filaments**).
 - b. How many gills are there on each side?
 - c. Observe that each gill is supported and kept in place by an arch of bones (**gill arch**).
 - d. Sketch a gill.
3. When the mouth of the fish opens, do the opercula open at the same time?
 Why does the fish open its mouth so frequently?
 Explain how a fish breathes.
 Does a fish drink? How do you know?

F. The Scales. Exoskeleton.

1. Show by a sketch the arrangement of the scales.
2. What advantages are there to the fish in having these scales?
3. Sketch a scale. (Dem.)
4. Compare a scale from the lateral line with an ordinary scale. Sketch.
5. Do the scales give the color to the fish?
6. Are the scales ctenoid or cycloid? **Ctenoid scales** have teeth on one edge while **cycloid scales** have no teeth.

G. Suggestive Questions.

1. Does a fish sleep? (Watch a goldfish at home.)
2. What is the "**swim-bladder**" of a fish? (Dem.)
3. On which one of its senses does a fish depend the most to warn it of approaching danger?
4. Is there anything peculiar about the way in which a dead fish floats?
5. Make a list of the principal fishes which are found alive in your neighborhood.

6. What are the principal fishing grounds in North America?
7. What are the most common food fishes found in the fish markets of your neighborhood? Where do they come from?
8. What is the United States Fish Commission?
9. What are the advantages of the backbone plan of structure?

2. THE FROG.

A. Habitat.

1. What is the habitat of the frog?

B. General Observations.

1. How is the shape of the frog adapted to its two methods of locomotion, jumping and swimming?
2. How is the frog's color adapted to conceal the frog? Are the black spots a help or a hindrance?
3. What is the arrangement of the black pigment spots on the back? On the hind legs when they are folded?
4. Observe the "hump" on the back.
5. Observe the looseness and moist condition of the skin.
6. Is there any exoskeleton?
7. Where are the frog's "croaking sacs"? (They are not always present.)
8. What is the resting position of a live frog? What advantage is there in this position?

C. The Head.

1. What is its shape?
2. Is there a neck? What is a "neck"?
3. The Eyes.

- a.* What is the shape of the external portion of the eyes? Compare with the eyes of a fish.
 - b.* Can they be retracted to avoid danger? (Touch the eye gently.)
 - c.* How many **eyelids** are there?
 - d.* How do the eyelids differ in structure and in use?
 - e.* What is the shape of the **pupil**?
 - f.* What is the color of the **iris**?
4. The Ears.
- a.* Observe the ear-drum (**tympanum**) just back of the eyes.
 - b.* Is the frog's hearing good? (Give reasons for your answer.)
5. The Nostrils.
- a.* How many **nostrils** are there?
 - b.* What is their position?
 - c.* Do they open through into the mouth? (Dem.)
 - d.* Is there any regular movement of the nostrils?

D. The Mouth.

1. Observe the extent to which the mouth can be opened.
 2. Notice its large broad cavity and the thin-walled throat.
 3. Observe also the movement of the throat in a live frog and note what the effect of this movement is on the size of the cavity.
4. The Tongue.
- a.* What is the shape of the **tongue**?
 - b.* Where is the tongue attached?
 - c.* What reason can you see for this mode of attachment?

5. The Teeth. (Feel for them with your finger or with a needle.)
 - a. Are **teeth** present on the upper jaw? On the lower jaw? On the roof of the mouth? (Compare with a skeleton of a frog.)
 - b. Does the frog chew its food?
What is the probable use of the teeth?
6. Identify the following openings into the mouth cavity, (Dem.) —
 - (a) the **oesophagus**;
 - (b) the **internal nostrils**;
 - (c) the **eustachian tubes**; (Their openings are near the angle of the jaws and lead to the ear.)
 - (d) the **glottis**, the opening of the wind pipe (**trachea**). It is slit-like and surrounded by cartilage.
7. Indicate the position of these openings and of the jaws, teeth and tongue in a sketch. (Represent the mouth wide open.)

E. The Fore Limbs.

1. Observe the division of the limb into the **upper arm**, (the proximal segment) the **forearm** and the **hand**.
2. How many fingers are there on each hand?
3. What are the uses of the fore limbs? (Observe the frog while at rest and while in motion.)
4. How are the fore limbs adapted to their uses?
5. Why cannot a frog jump by means of its fore limbs?
6. Is there any advantage in the way the frog "toes in"?
7. Make an outline drawing of a limb, showing its parts.

F. The Hind Limbs.

1. Observe the division of the hind limb into the **thigh**, (the proximal segment) the **shank** and the **foot**.
2. How many toes are there on each foot?
3. What is the advantage in having the limb attached so near the end of the body?
4. Compare with a skeleton of the frog and observe that the attachment of the limb to the body is really brought forward as far as the "hump" by another bone (**pelvic girdle**).

What is the advantage of having the point of attachment of the limb to the body so near the middle of the body?

5. What is the resting position of the hind limb? Why?
6. How is the limb adapted to jumping?
7. How is the limb adapted to swimming?
8. In what manner are the limbs used in jumping and swimming?
Why cannot the frog jump backward?
9. Make an outline drawing of the limb extended?

G. Respiration.

1. The Lungs. (Examine a frog dissected to show the **lungs**.)
 - a. Compare the size and appearance of inflated and uninflated lungs. Sketch.
 - b. Are the lungs spongy throughout or are they hollow? (Dem.)
 - c. Observe that each lung narrows into a short tube (**bronchus**), which connects it with the trachea.
 - d. Is there a diaphragm? The **diaphragm** is a mem-

brane separating the chest cavity from the abdominal cavity.

2. How are the nostrils used in respiration?
3. Is the mouth open in respiration?
4. What causes the air to flow into the mouth?
5. What forces the air into the lungs?
6. Why cannot a frog breathe as you do?
7. Does a frog breathe while under water? (Place a frog in a deep jar of water.)
8. Has the frog more than one method of respiration? Why must a frog keep its skin moist?

H. A Typical Muscle.

For this study examine the large **gastrocnemius muscle** of the shank, forming the "calf of the leg." (Use a dead frog with the skin stripped from the leg.)

1. What is the shape of this muscle?
2. Observe the **tendon**, a dense white portion at the end of the muscle by means of which it is attached to the bone.
3. Locate the points of attachment of the muscle to the bone. The proximal point of attachment is called the **origin** of the muscle and the distal, the **insertion**.
4. What parts of the limb are moved by this muscle?
5. What is the advantage of tendon?
6. Is the gastrocnemius a flexor or an extensor muscle?
7. Where is its opposing muscle? Why is this smaller?
8. Draw an outline of the leg to show the gastrocnemius with its opposing muscle and also their relation to the leg and foot.

I. The Liver and Heart. (Dem.)

The **liver** as seen from a ventral view is a large, dark-

red, lobed organ with the **heart** located anteriorly between two of its lobes.

1. The Liver.

- a.* Observe its size as compared with the heart.
- b.* How many lobes are there?
- c.* Is it firm in texture?
- d.* Identify the **bile sac**, a small greenish sac lying underneath, between two of the lobes of the liver.

2. The Heart.

- a.* What is its shape?
- b.* Observe its division into two **auricles** (the anterior portion) and a **ventricle** (the posterior conical portion).
- c.* In a split heart observe the difference in the thickness of the walls of the auricles and ventricle. Which is the thicker?
- d.* Observe an artery (**arterial trunk**) arising from the ventricle and passing forward over the auricles. It divides to the right and left into two branches, while each of these subdivides into three smaller branches called **arches**.

3. Draw the liver, and the heart with its arteries.

J. The Alimentary Canal, Etc.

1. Identify the four parts into which the alimentary canal is divided in the body cavity.
 - a.* The **œsophagus**, the short, wide, anterior portion leading from the mouth to the stomach.
 - b.* The **stomach**. (The œsophagus and the stomach together form the wide anterior portion of the canal.)
 - c.* The **small intestine**, the slender coiled part.

- d.* The **large intestine**, the wider, straight, posterior end of the canal.
2. What is the advantage in having the small intestine coiled instead of straight?
 3. Observe the folding of the inner wall of the stomach and of the small intestine. (Use split specimens.)
 4. Observe also the finger-like projections (**villi**) which cover the inner surface of the small intestine thickly, giving it a shaggy appearance.
 5. In a prepared section of the stomach observe the pit-like **digestive glands** of the **mucous membrane** or inner wall.
 6. What other parts of the alimentary canal are anterior to the œsophagus?
 7. How are the stomach and the intestine held in place in the body cavity?
 8. Accessory Organs. Identify, —
 - (a) the **pancreas**, an irregular-shaped gland between the stomach and first bend of the intestine;
 - (b) the **spleen**, a small, round, reddish gland near the anterior end of the large intestine;
 - (c) the **fat bodies**, yellow finger-like masses of fat.
 9. Make drawings to illustrate this section.

K. The Kidneys and their Veins.

The **kidneys** are two small, red, flattened bodies lying in the posterior dorsal portion of the body cavity. The two oval, yellowish bodies near the kidneys in the male frog are the **spermaries**. In the female frog will be found, similarly located, the **ovaries** filled with eggs.

1. Observe the large vein (**vena cava**) which takes its origin from the kidneys. (It lies between them.)

2. Observe also a vein (**renal portal**) connected with the outer border of each kidney.
3. Draw the kidneys with their veins.

L. The Spinal Nerves.

The **spinal nerves** lie in pairs against the dorsal body wall.

1. Identify ten pairs of spinal nerves.
2. Where do they originate and what is their relation to the backbone?
3. Trace each pair to find out what part of the body it supplies.
4. Which are the largest nerves? Why?
5. Which run together or unite to form a sort of network (**plexus**)?
6. Draw.

M. The Brain and Spinal Cord.

The **brain** and **spinal cord** form a large, white, soft tube seen when the backbone and the skull are laid open. The anterior lobed portion is the brain.

1. Why are the brain and cord so carefully protected?
2. The Brain.
 - a. Identify, beginning at the anterior end, —
 - (1) the **olfactory lobes**, two small lobes from each of which a nerve (**olfactory**) passes to the nostrils ;
 - (2) the **cerebral lobes**, two large, elongated lobes ;
 - (3) the **optic lobes**, two rounded lobes ;
 - (4) the **cerebellum**, a single, very small, median lobe ;

- (5) The **medulla**, the wedge-shaped posterior portion of the brain.
 - b. The depression seen in the medulla is a portion of the **cavity** of the hollow brain revealed by the cutting away of the very thin dorsal wall of this region.
3. The Spinal Cord.
 - a. What is its shape?
 - b. How far does it extend posteriorly?
 - c. Identify in a prepared cross-section, —
 - (1) the **dorsal** and **ventral grooves** ;
 - (2) the **central cavity** ;
 - (3) the two **roots** of a spinal nerve, on each side of the cord near the grooves ;
 - (4) the "**gray matter**" in the form of a letter H ;
 - (5) the "**white matter**" surrounding the gray matter.
 4. Draw the brain and spinal cord from the dorsal view.
 5. Make a diagram of a cross-section of the spinal cord.

N. The Skeleton.

1. Observe the division of the skeleton into two principal groups of bones : —
 - a. The **axial skeleton**, consisting of the bones of the head (**skull**) and the backbone (**vertebral column**).
 - b. The **appendicular skeleton**, consisting of the bones of the limbs and the **girdles** to which the limbs are attached.
2. The Skull.
 - a. **Premaxillaries** and **maxillaries**, the bones of the upper jaw.

- b.* **Dentary**, the lower jaw.
 - c.* **Vomer**, the bone bearing teeth in the roof of the mouth.
 - d.* **Cranium**, the brain-case.
 - e.* **Occipital foramen**, an opening in the posterior end of the cranium. What is it for?
 - f.* **Orbits**, the eye sockets.
3. The Vertebral Column.
- a.* **Vertebræ**, the small bones which make up the vertebral column. How many vertebræ are there?
 - b.* **Urostyle**, the blade-like bone at the end of the vertebral column.
 - c.* **Sacrum**, the vertebra to which the posterior appendicular skeleton is attached.
 - d.* **Atlas**, the first vertebra. How does it differ from the rest?
4. A Vertebra. (Use a vertebra from the skeleton of some mammal for comparison.)
- a.* **Centrum**, the ventral cylindrical portion of a vertebra.
 - b.* **Neural arch**, the arch of bones dorsal to the centrum. What does it enclose?
 - c.* **Neural spine**, a dorsal projection of the arch.
 - d.* **Lateral spines**, the paired lateral projections. Are ribs present? Sketch a vertebra.
- Why is the vertebral column made up of such a series of small bones?
5. The Pectoral Girdle.
- The **pectoral girdle** is the girdle of bones to which the fore limbs are attached. It consists of a series of bones which nearly encircle the body.
- a.* **Sternum**, the "breast-bone."

- b.* **Clavicle**, the "collar-bone."
- c.* **Coracoid**. (Both the clavicle and the coracoid articulate with the sternum. The coracoid is the longer and more posterior bone of the two.)
- d.* **Scapula**, the "shoulder-blade." (It is partly dorsal.)

Is the pectoral girdle attached to the backbone?

6. The Arm. (Fore limb.)

- a.* **Humerus**, the bone of the upper arm.
- b.* **Radio-ulnar**, the bone of the forearm. (Compare with the human arm.)

Why has it a double name?

- c.* **Carpals**, the bones of the wrist.
- d.* **Metacarpals**, the bones of the palm.
- e.* **Phalanges**, the bones of the fingers. How many in each finger? Compare with your own.
- f.* What sort of a joint do you find at the shoulder? At the elbow? At the wrist?

Why are the hand and wrist composed of so many small bones?

How is the human arm given greater freedom of motion than the frog's arm?

7. The Pelvic Girdle.

The **pelvic girdle** is the girdle of bones to which the hind limbs are attached. It resembles the "wish-bone" of a bird in shape.

- a.* Where is the girdle attached to the vertebral column?
- b.* Can you explain now how the "hump" is formed? What is the advantage of the "hump"?

8. The Leg. (Hind limb.)

- a.* **Femur**, the "thigh-bone." •

- b.* **Tibia-fibula**, the bone of the shank. Why is its name double?
- c.* **Tarsals**, the bones of the ankle. (Compare with the wrist and the human ankle.)
Why is the frog's "ankle" so long?
- d.* **Metatarsals**, the bones of the instep.
- e.* **Phalanges**, the bones of the toes. How many bones in each toe? Why are they so long?
What difference in structure makes possible in the live frog's leg a greater range of movement than in the arm?

9. Drawings.

O. Suggestive Questions.

1. Where is the frog in winter?
2. Does a frog breathe during hibernation?
3. Does a frog need food during hibernation? Why?
4. Where are the eggs of the frog deposited? At what time of the year?
5. Are the dark pigment spots exactly alike on all frogs?
6. Are the spots alike in the same frog at different seasons of the year?
7. Can a frog walk, run or float?
8. Are frogs of any economic importance?
9. What is the frog's protection from its enemies?
10. Make a diagram of a transverse section of the frog to show the relation of the neural cavity, spinal nerve cord, body cavity, alimentary canal and the body wall to each other.
11. Make a similar diagram of the transverse section of an earthworm showing the relation of the body cavity, alimentary canal, nerve cord and body wall to each other.

3. TADPOLES, A STUDY OF VERTEBRATE METAMORPHOSIS.

1. Arrange and number your specimens according to their ages.
2. What changes take place during metamorphosis in, —
 - (a) the head ;
 - (b) the body ;
 - (c) the tail ;
 - (d) the mouth ?

What is the use of the tail ?
What becomes of the tail when it disappears ?
3. Show by means of a sketch the arrangement of the muscles and the tail-fin.
4. Notice in some cases, through the transparent ventral body wall, the coiled intestine.
Why is the intestine in a tadpole so much longer than it is in the frog ?
5. Does the tadpole eat animal or vegetable food ?
6. When do the external gills appear and when do they disappear ?
7. Do you find outside traces of gills after the external gills have disappeared ?
8. Which pair of legs develops first ? Why ?
9. Are the legs well developed before the tail disappears ? Why ?
10. Make drawings to show the process of metamorphosis.

4. THE STUDY OF A BIRD SKIN.

A. In General.

1. What is the relative size of the head and the body ?
2. Is a distinct neck present ?

3. Observe the peculiar markings and coloring of your specimen.

B. Head.

1. What is the shape of the beak?
2. Exactly where are the "corners of the mouth"?
3. Are any hair-like structures around the mouth?
4. From the appearance of the beak what do you infer is the natural food of this bird?
5. What is the exact position of the nostrils?
6. Are the nostrils protected in any way?
7. Are the eyes protected in any way except by the eyelids?
8. Locate the bird's ears. Are they protected?

C. Wings.

1. Compare the length of the wings from shoulder to tip with that of the entire bird from the tip of the beak to the tip of the tail. (Make record.)
2. To what part of the skeleton are the wing-feathers attached? (Dem.)
3. Explain the advantage of the fan-like arrangement of the wings.

D. Tail.

1. What is the use of the tail? (Recall to mind birds that you have seen in flight.)
2. How does a bird's tail differ essentially from a tadpole's tail?
3. How does a bird's tail differ essentially from a cat's tail?

E. Feet.

1. How many toes on each foot?
2. How are the toes arranged?

What does this indicate in regard to the bird's habits?

3. What uses for the toes are suggested by their shapes?
4. Are scales present anywhere on the bird's foot?

Why should birds sometimes possess "scales" like reptiles?

F. Feathers.

1. What is the general arrangement of the feathers with regard to each other?
2. In what direction do the feathers extend? Why?
3. Compare, —
 - (a) wing feathers;
 - (b) tail feathers;
 - (c) contour feathers. (These feathers are the ones that give shape to the body of the bird.)
4. How are feathers better than scales?

G. Drawings.

1. The lateral view of the head.
2. The dorsal view of the beak.
3. A foot.

H. Original Observations.

Make any original observations about this bird that will indicate your keenness of insight.

5. A STUDY OF VERTEBRATE EXOSKELETONS.

A. The Scales of the Perch.

1. Are the scales embedded in the skin or do they lie upon its surface?
2. What parts of the fish are not covered with scales?
3. Are such parts protected in any other way?

4. How does the anterior portion of a scale differ from the posterior portion? (Remove a scale and examine, l. and l.p.)
5. What is the color of a scale?
6. Draw a scale (2 cm.).
7. How does a scale from the "lateral line" differ from the other scales? (Dem.) Show this by a drawing.

B. Comparative Study of Scales.

Prepare a table as indicated below and fill in answers to the following questions, using such scales for the study as your teacher may direct.

NO. OF QUESTION.	PERCH.	SALMON.	GARPIKE.	STURGEON.	SHARK.	LIZARD.	SNAKE.

1. Do the scales cover the entire body?
2. What parts, if any, are not covered with scales?
3. What is the arrangement of the scales with regard to each other? Show this arrangement by a sketch of a small patch of scales.
4. Are the scales thin like perch scales or are they thickened?
5. What markings or ornamentations, such as radiating or concentric lines, projections, etc., have the scales?
6. What is the use of the scales to each animal?

C. The Turtle Shell.

1. What parts of the body are not protected by the shell?

2. What is done with these parts in times of danger?
3. What effect does such a shell have upon the movements of the turtle?

4. Parts of the Shell.

- a.* The **carapace**, the dorsal portion.
- b.* The **plastron**, the ventral portion.
- c.* The **bridge**, the lateral connecting portions.

5. The Dermal Plates.

The **dermal plates** are the "scales" which form the outer covering of the shell.

- a.* What color markings are there on these plates?
 - b.* What is the arrangement of the plates on the carapace? On the plastron?
 - c.* Is this arrangement of the plates the same for all turtles?
 - d.* What variations do you find in the texture of the dermal plates of turtles?
6. Make two drawings of the shell, one of the carapace and one of the plastron.

7. The Bony Shell.

The **bony shell** is the shell which lies beneath the dermal plates and may be seen by removing these plates. (Dem.)

- a.* Is this shell thicker or thinner than the dermal shell?
- b.* Is the arrangement of the bony plates the same as that of the dermal plates?
- c.* Observe the fusion of the ribs and backbone with the bony shell.

Is it correct to include a study of the bony shell in a study of exoskeletons?

8. What exoskeletal parts besides the shell has the turtle?

D. The Feathers of the Pigeon.

1. What parts of the body are not clothed with feathers?
2. Are these parts protected in any other way?
3. Have the feathers a regular arrangement like fish scales?
4. Why are feathers always directed backward?
5. Is the contour (outline) of the body made more regular by being clothed with feathers?
6. Identify the following varieties of feathers:—
 - a. **Tail-feathers.**
 - b. **Wing-feathers.**
 - (1) **Primaries**, the feathers attached to the hand and wrist.
 - (2) **Secondaries**, the feathers attached to the forearm.
 - (3) **Coverts**, the feathers covering the rest of the wing.
 - c. **Contour-feathers**, the feathers which give shape to the body.
 - d. **Down-feathers**, small feathers without definite outline lying next to the body.
7. Which are the strongest feathers? Why?
8. Identify the following parts of a tail- or wing-feather, —
 - (a) the **shaft**, the central axis of the feather;
 - (b) the **quill**, the proximal hollow part of the shaft;
 - (c) the **vane**, the flat lateral parts of the feather;
 - (d) the **barbs**, the parts which make up the vane;
 - (e) the **barbules**, the small branches of each barb.

(The barbules on one side of the barb may be called distal, those on the other side proximal.)
9. Observe (1) the arrangement of the barbs and barbules with regard to each other. Show this ar-

rangement by a sketch of two adjacent barbs with their barbules.

10. Find the small "hooks" on the barbules for hooking the barbs together. (l.p.)
11. Are the hooks on the distal or on the proximal barbules?
Why is it necessary for the barbs to be hooked together?
Why would not a solid, leaf-like feather answer as well?
12. Have birds any other exoskeletal parts besides feathers?
Why are feathers better than scales?
13. Draw a feather.

E. Hair or Fur.

1. What are the advantages of a hairy covering?
2. Are there any hairs which have a sensory function?
3. How does the root differ from the shaft in color?
The part of a hair which is embedded in the skin is called the **root** and the remaining portion is the **shaft**.
4. In a prepared section of the scalp observe (l.p.), —
 - (a) the **hair follicle**, the pocket of the skin in which the root of the hair is embedded;
 - (b) the **papilla**, the small knot of blood-vessels and nerves in the enlarged base of the root;
 - (c) the **oil gland**, lying beside the follicle and opening into it;
 - (d) the **hair muscle**, which runs from the base of the follicle diagonally to the surface of the scalp.
What is the use of this muscle?
5. Make a diagram to illustrate E 4.

6. What is meant by “shedding the hair”? What advantage is gained by it?

Why does the color of many furry animals change with the season? How does this take place?

6. A COMPARATIVE STUDY OF LIVING VERTEBRATES.

Prepare a table and fill out, for each animal studied, as indicated below. Do not guess at the answers but make careful observations in every case. Record what your particular specimen shows and remember that negative results are often of great significance. If you cannot answer a question put an interrogation point (?) in place of the answer.

TOPIC.	NO. OF QUESTION.	A FISH.	A TAILED AMPHIBIAN.	A TAIL-LESS AMPHIBIAN.	A REPTILE.	A BIRD.	A MAMMAL.

A. Symmetry.

1. What is the form of symmetry?

B. Shape of the Body.

1. Sketch the lateral view of the animal.
2. Sketch the anterior view of the animal.
3. Is the body compressed or flattened?
4. Is the shape of the body especially adapted to life in the water, on the land or in the air?
5. How is the body adapted to this environment?

C. Locomotion.

1. Name all the different methods of locomotion you observe.

2. By means of what structures is each method accomplished?
3. How many sets of paired appendages are there? (If there are two sets, distinguish them as anterior and posterior.)
4. How many median appendages are there? (Any structure supported by the continuation of the vertebral column is not an appendage.)
5. Do the paired appendages support the body?
6. What other uses have the appendages besides aiding in locomotion?

D. Response to Stimulus. (Dem.)

1. Does the animal respond to the following forms of stimulus, —
 - (a) tactile (“touch”);
 - (b) auditory (sounds);
 - (c) light;
 - (d) chemical?
2. What senses do you infer are present?
3. Name the sense organs you see.
4. Show the position of these organs by means of a sketch.

E. Sense Organs.

1. The Eyes.
 - a. Can the eyes be closed?
 - b. How many eyelids are present?
 - c. Which eyelids are present?
 - d. Show by a sketch the size and shape of the pupil.
2. The Nostrils.
 - a. Is there any peculiar movement of the nostrils?
 - b. Is this connected with breathing or with smelling?

3. The Tongue.

a. What uses has it?

4. Tactile Organs.

a. Do you find any?

b. If so, what are they?

5. Balancing Organs.

a. Do you find any?

b. Has the animal more than one means of balancing?

F. Feeding.

1. If possible watch the animals feed and drink.
(Make a check mark in your table if you have done so.)

G. Respiration.

1. Does the animal breathe by means of lungs, gills or the skin?
2. *If by lungs*, note carefully any movements of the sides and throat. Is the air breathed in by swallowing or by means of a diaphragm?
If by gills, identify them and show by a diagram the course of the water in the process of respiration.

H. General Questions.

1. How is the animal especially adapted to its mode of life?
2. What means of protection has it?
3. With what offensive or defensive weapons is it provided?
4. What seems to you to be the most characteristic thing about the animal?
5. According to your table, what points are common to all vertebrates?

7. A ZOOLOGICAL STUDY OF MAN. *Homo sapiens.*

1. How does the habitat of man differ from that of all other animals?
2. What factors restrict the distribution of man over the earth?
3. How do man's natural methods of locomotion compare in variety and efficiency with those of the lower animals?
4. Wherein lies man's great advantage over other animals with regard to locomotion?
5. How has man been able to succeed in all climes with such a poor natural protective covering of the body?
6. What does the presence of incisors, canines, præmolars and molars indicate regarding the natural food of man?
7. Why does it take man comparatively so much longer to become able to shift for himself after birth than it does any other animal?
8. Instead of being obliged to learn how to do things, would it be an advantage to man to be born with instinctive knowledge, as many animals are? Why?
9. Does the muscular system reach its highest development in man or in some of the lower animals? Why?
10. The sense of smell in man is inferior to that in the dog. What has brought about this result?
11. Similarly the sense of sight in man is inferior to that of the bird. What has brought about this result?
12. Why is it unlikely that the natural sight of man will ever improve in the ages to come?
13. Why is the "sense of direction" in man inferior to that of bees, birds and many other animals?

14. Does man have any balancing organs?
15. Are dogs, cats and animals in general ever "right-handed"? What is the significance of right-handedness in man?
16. How does the relative size of the face-bones and the brain-case (**cranium**) compare in man and any lower vertebrate? Why?
17. Is man the only animal that can converse?
18. How does the upright position of man affect, —
 - (a) the use of the arms;
 - (b) the carrying of the head;
 - (c) the form of the body (*i.e.* whether it is "compressed" or "flattened")?
19. To appreciate the hands as organs of prehension try to get along without them for a time, as other animals always do, — during lunch, for instance.
20. What would be the effect of hands without thumbs? (Try in various ways to use your hands without using your thumbs.)
21. What traces of an invertebrate exoskeleton are still present in man?
22. Is there anything about the life history of man to suggest the metamorphosis of insects?
23. Does the moulting of the arthropods find any counterpart in man?
24. Is there any trace of the somite plan of structure in man?
25. Can you think of any modification of "plans of structure" which might in time develop an animal superior to man?
26. Are "protective colorings," so often noticed among lower animals, at all characteristic of man? Why?
27. How can we explain the presence in man of such a

structure as the *vermiform appendix*, since its presence is an injury rather than a benefit?

28. What are the essential differences between the human brain and that of the frog?
29. Why is the scientific name of man well chosen?
30. State facts to show that in man the *moral law* takes precedence over the law of the "survival of the fittest."
31. Is it of advantage to the physical development of man that the "moral law" takes precedence over the law of the "survival of the fittest"?
32. Summarize your reasons why man is the most superior animal.

8. A COMPARATIVE REVIEW OF IMPORTANT TYPES.

Prepare a table similar to the one indicated below, placing the name of the animal studied at the head of the column. Use the left-hand column for the topic number.

TOPIC.	PARAMECIUM.	GRANTIA.	HYDRA.	EARTHWORM.	STARFISH.	CRAYFISH.	LOCUST.	CLAM.	GOLDFISH.	FROG.	BIRD.	MAN.

1. What is the form of symmetry?
2. What kind of a skeleton does the animal have?
3. What distinctive principle does the animal illustrate?

4. What is the position of the "nerve cord" with relation to the alimentary canal?
5. By what means is respiration accomplished?
6. By what means is circulation accomplished?
7. How is locomotion accomplished?
8. Enumerate the sense organs with which you are acquainted.

A TABLE OF CLASSIFICATION OF THE ANIMAL KINGDOM.

BRANCHES.	CLASSES.	EXAMPLES MENTIONED IN THIS BOOK.
PROTOZOA . . .	Rhizopoda . . .	Amœba
	Infusoria . . .	Paramœcium, Vorticella
	Sporozoa . . .	
PORIFERA . . .	Calcispongiæ . . .	Grantia
	Silicispongiæ . . .	Spongilla
	Ceratospongiæ . . .	Euspongia
CŒLENTERATA .	Hydrozoa . . .	Hydra, Hydroids, Hydro-medusa
	Actinozoa . . .	
	Ctenophora . . .	
VERMES . . .	Platyhelminthes .	Planarian Worm
	Nemathelminthes	
	Annelida . . .	Earthworm, Marine Annelid
	Rotifera . . .	
ECHINODERMATA	Asteroidea . . .	Starfish
	Echinoidea . . .	Sea-urchin
	Holothuroidea . .	Sea-cucumber
	Crinoidea . . .	
ARTHROPODA .	Crustacea . . .	Crayfish, Crab, Fairy Shrimp, Pill-bug
	Myriapoda . . .	Milliped
	Octopoda . . .	Spider
	Hexapoda . . .	Grasshopper, Moth, Mosquito, All Insects of Study VI. 8
MOLLUSCA .	Pelecypoda . . .	Fresh-water Clam
	Gasteropoda . . .	Snail
	Cephalopoda . . .	Squid
VERTEBRATA .	Acrania . . .	
	Pisces . . .	Goldfish, Perch, other fishes (p. 95)
	Amphibia . . .	Frog, Tadpole
	Reptilia . . .	Lizard, Snake, Turtle
	Aves . . .	Bird
	Mammalia . . .	Cat, Dog, Man

ADVERTISEMENTS

Mathematics

- Barton's Theory of Equations.** A treatise for college classes. \$1.50.
- Bowser's Academic Algebra.** For secondary schools. \$1.12.
- Bowser's College Algebra.** A full treatment of elementary and advanced topics. \$1.50.
- Bowser's Plane and Solid Geometry.** \$1.25. PLANE, bound separately. 75 cts.
- Bowser's Elements of Plane and Spherical Trigonometry.** 90 cts.; with tables, \$1.40.
- Bowser's Treatise on Plane and Spherical Trigonometry.** An advanced work for colleges and technical schools. \$1.50.
- Bowser's Five-Place Logarithmic Tables.** 50 cts.
- Fine's Number System in Algebra.** Theoretical and historical. \$1.00.
- Gilbert's Algebra Lessons.** Three numbers: No. 1, to Fractional Equations; No. 2, through Quadratic Equations; No. 3, Higher Algebra. Each number, per dozen, \$1.44.
- Hopkins's Plane Geometry.** Follows the inductive method. 75 cts.
- Howland's Elements of the Conic Sections.** 75 cts.
- Lefevre's Number and its Algebra.** Introductory to college courses in algebra. \$1.25.
- Lyman's Geometry Exercises.** Supplementary work for drill. Per dozen, \$1.60.
- McCurdy's Exercise Book in Algebra.** A thorough drill book. 60 cts.
- Miller's Plane and Spherical Trigonometry.** For colleges and technical schools. \$1.15.
With six-place tables, \$1.40.
- Nichol's Analytic Geometry.** A treatise for college courses. \$1.25.
- Osborne's Differential and Integral Calculus.** \$2.00.
- Peterson and Baldwin's Problems in Algebra.** For texts and reviews. 30 cts.
- Robbins's Surveying and Navigation.** A brief and practical treatise. 50 cts.
- Schwatt's Geometrical Treatment of Curves.** \$1.00.
- Waldo's Descriptive Geometry.** A large number of problems systematically arranged and with suggestions. 80 cts.
- Wells's Academic Arithmetic.** With or without answers. \$1.00.
- Wells's Essentials of Algebra.** For secondary schools. \$1.10.
- Wells's Academic Algebra.** With or without answers. \$1.08.
- Wells's New Higher Algebra.** For schools and colleges. \$1.32.
- Wells's Higher Algebra.** \$1.32.
- Wells's University Algebra.** Octavo. \$1.50.
- Wells's College Algebra.** \$1.50. Part II, beginning with quadratics. \$1.32.
- Wells's Essentials of Geometry.** (1899.) \$1.25. PLANE, 75 cts. SOLID, 75 cts.
- Wells's Elements of Geometry.** Revised. (1894.) \$1.25. PLANE, 75 cts.; SOLID, 75 cts.
- Wells's New Plane and Spherical Trigonometry.** For colleges and technical schools. \$1.00. With six place tables, \$1.25. With Robbins's Surveying and Navigation, \$1.50.
- Wells's Essentials of Trigonometry.** For secondary schools. 90 cts. With tables, \$1.08. PLANE, bound separately, 75 cts.
- Wells's New Six-Place Logarithmic Tables.** 60 cts.
- Wells's Four-Place Tables.** 25 cts.

For Arithmetics see our list of books in Elementary Mathematics.

D. C. HEATH & CO., Publishers, Boston, New York, Chicago

Science.

- Ballard's World of Matter.** A guide to mineralogy and chemistry. \$1.00.
- Benton's Guide to General Chemistry.** A manual for the laboratory. 35 cts.
- Boyer's Laboratory Manual in Biology.** An elementary guide to the laboratory study of animals and plants. 80 cts.
- Chute's Physical Laboratory Manual.** A well-balanced course in laboratory physics, requiring inexpensive apparatus. Illustrated. 80 cts.
- Chute's Practical Physics.** For high schools and colleges. \$1.12.
- Clark's Methods in Microscopy.** This book gives in detail descriptions of methods that will lead any careful worker to successful results in microscopic manipulation. \$1.60.
- Coit's Chemical Arithmetic.** With a short system of analysis. 50 cts.
- Colton's Physiology.** Experimental and descriptive. For high schools and colleges. Illustrated. \$1.12.
- Colton's Physiology, Briefer Course.** For earlier years in high schools. Illustrated. 00 cts.
- Colton's Practical Zoology.** Gives a clear idea of the subject as a whole by the careful study of a few typical animals. 80 cts.
- Grabfield and Burns's Chemical Problems.** For review and drill. Paper. 25 cts.
- Hyatt's Insecta.** Illustrated. \$1.25.
- Orndorff's Laboratory Manual.** Contains directions for a course of experiments in Organic Chemistry, arranged to accompany Remsen's Chemistry. Boards. 35 cts.
- Remsen's Organic Chemistry.** An introduction to the study of the compounds of carbon. For students of the pure science, or its application to arts. \$1.20.
- Roberts's Stereo-Chemistry.** Its development and present aspects. \$1.00
- Sanford's Experimental Psychology.** Part I. Sensation and Perception. \$1.50.
- Shaler's First Book in Geology.** For high school, or highest class in grammar school. \$1.00. Bound in boards for supplementary reader. 60 cts.
- Shepard's Inorganic Chemistry.** Descriptive and qualitative; experimental and inductive; leads the student to observe and think. For high schools and colleges. \$1.12.
- Shepard's Briefer Course in Chemistry,** with chapter on Organic Chemistry. For schools giving a half year or less to the subject, and schools limited in laboratory facilities. 80 cts.
- Shepard's Laboratory Note-Book.** Blanks for experiments; tables for the reactions of metallic salts. Can be used with any chemistry. Boards. 35 cts.
- Spalding's Introduction to Botany.** Practical exercises in the study of plants by the laboratory method. 80 cts.
- Stevens's Chemistry Note-Book.** Laboratory sheets and cover, with separate cover for permanent file. 50 cts.
- Venable's Short History of Chemistry.** \$1.00.
- Whiting's Physical Measurement.** I. Fifty measurements in Density, Heat, Light, and Sound. II. Fifty measurements in Sound, Dynamics, Magnetism, Electricity. III. Principles and Methods of Physical Measurement, Physical Laws and Principles, and Mathematical and Physical Tables. IV. Appendix. Parts I-IV, in one vol., \$4.00.
- Whiting's Mathematical and Physical Tables.** Paper. 50 cts.
- Williams's Modern Petrography.** Paper. 25 cts.

*For elementary works see our list of
books in Elementary Science.*

D.C. HEATH & CO., Publishers, Boston, New York, Chicago.

Wells's Mathematical Series.

ALGEBRA.

Wells's Essentials of Algebra \$1.10

A new Algebra for secondary schools. The method of presenting the fundamental topics is more logical than that usually followed. The superiority of the book also appears in its definitions, in the demonstrations and proofs of general laws, in the arrangement of topics, and in its abundance of examples.

Wells's New Higher Algebra 1.32

The first part of this book is identical with the author's Essentials of Algebra. To this there are added chapters upon advanced topics adequate in scope and difficulty to meet the maximum requirement in elementary algebra.

Wells's Academic Algebra 1.08

This popular Algebra contains an abundance of carefully selected problems.

Wells's Higher Algebra 1.32

The first half of this book is identical with the corresponding pages of the Academic Algebra. The latter half treats more advanced topics.

Wells's College Algebra 1.50

A modern text-book for colleges and scientific schools. The latter half of this book, beginning with the discussion of Quadratic Equations, is also bound separately, and is known as Wells's College Algebra, Part II. \$1.32.

Wells's University Algebra 1.32

GEOMETRY.

Wells's Essentials of Geometry — Plane, 75 cts.; Solid, 75 cts.;
Plane and Solid 1.25

This new text offers a practical combination of more desirable qualities than any other Geometry ever published.

Wells's Stereoscopic Views of Solid Geometry Figures60

Ninety-six cards in manila case.

Wells's Elements of Geometry — Revised 1894. — Plane, 75 cts.;
Solid, 75 cts.; Plane and Solid 1.25

TRIGONOMETRY.

Wells's New Plane and Spherical Trigonometry (1896) . . . \$1.00

For colleges and technical schools. With Wells's New Six-Place Tables, \$1.25.

Wells's Plane Trigonometry75

An elementary work for secondary schools. Contains Four-Place Tables.

Wells's Essentials of Plane and Spherical Trigonometry90

For secondary schools. The chapters on Plane Trigonometry are identical with those of the book described above. With Tables, \$1.08.

Wells's New Six-Place Logarithmic Tables60

The handsomest tables in print. Large Page.

Wells's Four-Place Tables25

ARITHMETIC.

Wells's Academic Arithmetic \$1.00

*Correspondence regarding terms for introduction
and exchange is cordially invited.*

D. C. HEATH & Co., Publishers, Boston, New York, Chicago

Higher English.

- Bray's History of English Critical Terms.** A vocabulary of 1400 critical terms used in literature and art, with critical and historical data for their study. Cloth. 351 pages. \$1.00.
- Cook's Judith.** With introduction, translation and glossary. Cloth. 170 pages. \$1.00. *Student's Edition*, without translation. Paper. 104 pages. 30 cents.
- Hall's Beowulf.** A metrical translation of this ancient epic. Octavo. 118 pages. Cloth, 75 cents. Paper, 30 cents.
- Kluge and Lutz's English Etymology.** A select glossary for use in the study of historical grammar. Cloth. 242 pages. 60 cents.
- MacEwan's The Essentials of Argumentation.** A systematic discussion of principles, with illustrative extracts; full analysis of several masterpieces, and a list of propositions for debate. Cloth. 430 pages. \$1.12.
- Meiklejohn's The English Language.** Part I—English Grammar; Part II—Composition and Versification; Part III—History of the English Language; Part IV—History of English Literature. Cloth. 396 pages. \$1.20.
- Meiklejohn's English Grammar.** Contains Part I and II of Meiklejohn's The English Language, with exercises. Cloth. 276 pages. 80 cents.
- O'Connor's Rhetoric and Oratory.** A manual of precepts and principles, with masterpieces for analysis and study. Cloth. 352 pages. \$1.12.
- Pearson's The Principles of Composition.** Begins with the composition as a whole. Paragraphs, sentences and words are treated later, and in this order. Cloth. 165 pages. 50 cents.
- Strang's Exercises in English.** Examples in Syntax, Accidence, and Style, for criticism and correction. New edition, revised and enlarged. Cloth. 160 pages. 45 cents.
- William's Composition and Rhetoric.** Concise, practical, and thorough, with little theory and much practice. Cloth. 344 pages. 90 cents.

Monographs on English.

Bowen's Historical Study of the O-vowel.	Cloth. 109 pp.	. . .	\$1.25
Genung's Study of Rhetoric in the College Course.	Paper. 32 pp.25
Hempl's Chaucer's Pronunciation.	Stiff Paper. 39 pp.50
Huffcut's English in the Preparatory School.	Paper 28 pp.25
Woodward's Study of English.	Paper. 25 pp.25

*See also our list of books in Elementary English,
English Literature and English Classics.*

D. C. HEATH & CO., Publishers, Boston, New York, Chicago

