SCIENCE TEXT-BOOKS

ELEMENTARY BIOLOGY

BAYER

D. C. HEATH & CO.

A LABORATORY MANUAL

IN

ELEMENTARY BIOLOGY

AN

INDUCTIVE STUDY IN ANIMAL AND PLANT MORPHOLOGY

DESIGNED FOR PREPARATORY AND HIGH SCHOOLS

BY

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PREFACE.

It is important that the pupil should find included in his high school or preparatory course a line of work which embraces the study of natural objects and phenomena. Such are the so-called science studies, provided they are really studies of the objects instead of books. But in these studies the young beginner must be guided and directed, in order that his observations and inferences may be comprehensive, systematic and accurate; hence the laboratory manual is an absolute necessity where the teacher is to direct a class of any considerable number of pupils in practical work.

This book is the outgrowth of several years' experience in an effort to place the subjects of elementary zoölogy and botany upon a strictly laboratory basis in preparatory and high schools, and to combine the study of animals and plants as parts of one subject, Biology. It has been my effort to make the laboratory studies as strictly *inductive* as I could, bearing in mind the condition of the average young student, viz., his comparative ignorance of the subject-matter, and his limited experience in continuous and systematic observation, and in faithful, accurate description of what he sees.

To Prof. S. A. Forbes, University of Illinois, Prof. C. O. Whitman, University of Chicago, President J. M. Coulter, Lake Forest University, Prof. C. E. Bessey, University of Nebraska,

Prof. B. P. Colton, Illinois State Normal, Supt. G. W. Peckham, Milwaukee Public Schools, and to Dr. A. F. Nightingale, Superintendent of the High Schools of Chicago, I wish here to express my sincere thanks for their encouragement and valuable suggestions.

I am much indebted to the teachers of biology in the Chicago High Schools for their cordial coöperation, and especially to those who have kindly assisted in reading the proof.

Unavoidably the book has been hurried in its progress through the press and will not therefore be as free from error as could ordinarily be expected, and I respectfully request the forbearance of teachers of biology and educational friends.

E. R. B.

CHICAGO, February, 1894.

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INTRODUCTION.

In arranging this Manual the author has attempted primarily to meet the demand of those high schools and preparatory institutions which desire to combine the subjects of zoölogy and botany into a continuous one-year study, and make laboratory work the basis. It has been the aim to arrange a series of studies which will give the pupil, through his own observations, a knowledge of the leading characteristics of the chief branches of animals and plants. In its nature the laboratory work consists almost entirely of morphology, and comparatively little actual dissection is required of the pupil; hence the course is more truly one in animal and plant morphology than biology in the broader sense.

The method of instruction is inductive and rests upon the individual observation of the pupil. The aim is to develop rather than inform; hence the laboratory method of study is more important than the information involved. Accuracy in observation is a prerequisite to accuracy and clearness in description or statement, as well as to logical inference or conclusion.

Each pupil should be provided with both material for study, and a copy of the Manual to direct him. The class being so provided, the instructor is free to render such individual

assistance as may be necessary in the technique and execution of the work. The pupil studies the material as directed in the Manual, and notes the facts of his observations and the conclusions drawn from them His notes, illustrated by numerous sketches, of the structures studied, are subsequently to be cast into clear, concise, and connected statements, constituting a description of the plant or animal under consideration.

Careful drawings may also be made upon a standard drawing paper, the aim of which is to represent a summary of the principal structural characteristics of the type studied. The sketches and drawings should be diagrammatic, clear and distinct in outline, without any attempt to represent light and shade or to produce artistic effect.

The material required in this course is of mere nominal expense, but requires some time in its preparation. Any instructor acquainted with modern methods of laboratory technique can, by the aid of some of his pupils, make the necessary permanent preparations in course of one or two terms, and when once accumulated, the preparations may be kept from year to year. It is not necessary that all the material enumerated should be provided before introducing this course.

When a technical term is introduced for the first time it appears in full-face type and stands in a sentence embodying its definition. The *Index* contains the derivation of all such terms. The literal meaning of the technical terms, if associated with their present or special meaning, will aid the pupil in

understanding the force and propriety of their application, as well as aid his memory in retaining them.

The synopses of classification and the artificial key arranged for a few typical plants will afford some practical work in "plant analyses," and will also aid in impressing the pupil with the natural affinity and unity in the world of living beings.

The references at the close of each Study refer to the Works of Reference on page 203. In order to economize space and avoid many repetitions of titles, the references are made by numerals.

PRELIMINARY EXERCISE.

REMARK. — A preliminary exercise on the manipulation and use of the microscope is necessary to successful work with beginners in this course. It should not fail to precede the practical use of the microscope. Owing to its compactness and simplicity, the pattern known as the "Continental Stand" is to be preferred for beginners in an elementary course.* The following introductory exercise will, however, apply almost equally well to other forms of stand. The instructor should see that all accessories not recognized in the exercise are removed from the stand and that the eyepiece and objective are not in the tube at the time of beginning the exercise.

THE COMPOUND MICROSCOPE.

(*a*) Observe the general appearance and construction of the body (**stand**) of the microscope. Note the part (**base**) which rests on the table. What is its shape? Examine the vertical part (**column**), which is attached to the base and gives support to the other parts. In some microscopes the column is provided with a hinge a short distance above the base, which allows the column to turn back in an oblique position. Do you find such a hinge in this microscope?

(*b*) Observe the horizontal shelf-like part (**stage**) attached to the column. The use of the stage is to support the object or preparation while it is being studied with the microscope. Note the circular opening (**eye**) through the central part of the stage. The use of the eye is to allow light to pass up through the stage.

* See note on page 194.

(*c*) Tip the microscope to one side, and examine the lower surface of the stage. Do you find any device (**diaphragm**), possibly a rotary disc, attached to the stage? Observe the series of openings in the diaphragm, and rotate the disc so as to bring successively openings of different size in range of the eye of the stage. The use of the diaphragm is to regulate the amount of light allowed to pass through the stage.

(*d*) Observe the springs (**clips**) on the stage, one to the right and the other to the left of the column. Remove the clips and then return them to their proper places. The clips are used to hold a slip of glass (**object-slide**) in proper position on the stage. Take a clean object-slide and place it on the stage over the eye, and fasten it in position with the clips. Now remove it.

(*e*) Observe the slightly concave glass (**mirror**), a little distance below the stage. The mirror is used to collect the rays of light and reflect them through the eye of the stage to illuminate the object. Observe the freedom and ease with which the mirror turns to enable you to get the light from almost any direction.

(*f*) Observe the large tube (**sliding-tube**) directly above the stage. With your left hand move the tube up and down, while you hold the stand firmly on the table with your right hand. Observe that the tube is loosely clasped within an outer tube (**sleeve**). Move the tube up and down, at the same time slowly revolving it in the sleeve, to see how steady and uniform and slow you can make the movement.

(*g*) At the top of the column observe the large head of a screw (**milled head**). Turn it back and forth, and at the same time carefully watch the lower end of the tube. What is the effect? The use of the milled head is to move the draw-tube up and down through a very short

distance (**fine adjustment**). When you wish to move the tube a long distance (**coarse adjustment**), you accomplish it by moving it through the sleeve by hand, in the way you have already practiced. In some microscopes the coarse adjustment is accomplished by means of a large milled head at the side of the tube, which operates a rack and pinion.

(*h*) Remove the tube entirely from the sleeve. Let the left hand do this while the right hand holds the stand firmly on the table. Point the tube toward the light and look through it. You see that it is merely an open tube without any glass. Now replace the tube, carefully observing the former directions.

(*i*) Take the small metallic cylinder (**ocular** or **eye-piece**) from the table and examine it. Observe that it has a glass lens at each end. You should be very careful not to touch a lens, especially *never* with your fingers. Hold the eye-piece toward the light, the smaller lens next to your eye, and look through it.

(*j*) Observe the circular illuminated area (**field of vision**). Turn it toward the darkest part of the room to observe the difference in the illumination of the field. Now point the eye-piece toward the clear sky, or a white cloud, and observe that you get a beautiful field of white light. This is the best kind of light for the microscope. You should avoid getting the direct rays of the sun. Place the eye-piece in the upper end of the tube, which is its proper position.

(*k*) Now sit close to the table, allowing your forearms to rest on the edge. Move the microscope directly in front of you, placing it so that the column shall be next to you and the stage extending away from you. This is the position which you should *always* take with the microscope.

(*l*) Look down through the eye-piece and tube, and at the same time illuminate the field, using your left hand at the mirror. Get the light from the window which is most nearly in front of you and gives you the most favorable light. While you are moving the mirror, carefully watch the field in order to secure the best illumination. When you have secured a well-illuminated field, turn the mirror very little until only a portion of the field has good light. This is to be avoided. You should always have the field lighted uniformly. Now turn the mirror in a wrong direction, and see how quickly you can again get good illumination. Let the instructor now see whether you have a good field.

(*m*) When you have secured the best illumination, modify the light by the use of the diaphragm, carefully observing the effect on the illumination of the field. Observe that when the largest opening is in range of the field, the largest amount of light reflected from the mirror is admitted, while the other openings admit relatively smaller amounts. Move the microscope back out of your way.

(*n*) Now take the lower magnifying power (**objective**) from the table and examine it; observe the lens in the tapering end, and remember not to touch it. Observe that the larger end is an open tube and has a screw-thread. This end is intended to screw into the lower end of the tube. The objective, together with the eye-piece, constitute the magnifying parts of the microscope. The *eye-piece* is so called because it contains the system of lenses which is next to the eye of the observer while in use. The *objective* is so called because it contains the system of lenses next to the object of study. A microscope which has these two systems of lenses is called a *Compound microscope*.

(*o*) Take the objective, and look through it at a letter in your open book on the table. Hold the smaller end of the objective about a half-inch from the page. Bring your eye about one inch from the larger end of the objective. Now gradually move the objective farther away from the printed letter until you reach the place (**focus**) where you can see the letter most distinctly. Now look at other letters, and be sure to find the exact focus.

(*p*) Bring the microscope up into position again, and remove the tube, allowing your index finger to touch the upper rim of the eye-piece to prevent its sliding out of the tube. Now hold the tube horizontally and close to the table in front of the microscope, while you take the objective with your right hand and screw it into the tube. Return the tube, with objective, to the sleeve.

(*q*) Take a slide which contains a small letter or figure mounted, look through the slide toward the light, and see what it is. Observe that the object is fastened to the slide under a very thin film of glass (**cover-glass**). You should avoid touching the cover-glass of a preparation, and, in placing a slide on the stage, the cover-glass should *always* be uppermost. Now place the slide on the stage so that the object which is mounted under the cover-glass shall be in the centre of the eye of the stage. Fasten the slide in position by means of the clips.

(*r*) Now, by means of the coarse adjustment, having your left hand on the draw-tube, gradually bring down the objective to about one-quarter of an inch from the slide. Do not look through the tube while you are moving it down toward the object, but carefully watch the objective on the outside, with your eye nearly on a level with the stage. The objective is now supposed to be nearer the object than the proper focal plane: hence when

you move it slowly upward, while looking in the tube, you can find the focus and see the object, but before you focus, you should illuminate the field.

(*s*) Now, while *looking through* the *tube*, illuminate the field; and then, by gradually drawing the tube *up*, find the focus. As soon as you discover any trace of the object, stop and use the *fine adjustment*, to get the exact focus. If the object happens not to be properly in the field, you can move the slide very little on the stage.

(*t*) Now remove the clips entirely, and then remove the slide from the stage, being careful not to lift it, as it might touch the lens in the objective. In handling a preparation on the stage, you should slide it on or off the stage, but never lift it.

(*u*) Remove the slide and hold it so that the figure or letter is in a proper position to be read; now return it to the stage and observe its direction under the microscope. It seems that the right and left sides have exchanged places and that the object is inverted. Under the compound microscope an object is seen as if it had revolved 180°, or half a revolution, in a horizontal plane. Make sure that you understand this.

(*v*) Now remove the objective and put on the higher power instead, being very careful to follow former directions. In using the higher power, it is necessary to bring it nearer to the object before beginning to focus with the coarse adjustment. With some higher powers you need to begin within an eighth of an inch. You may now find the focus, as you did in case of the lower power, only using greater care and making the adjustment more gradually.

SUMMARY OF THE STEPS IN MANIPULATING THE MICROSCOPE.

Preparatory to Study.

1. Put on eye-piece and objective.
2. Illuminate the field.
3. Place preparation on stage.
4. Move objective below focal plane.
5. Find the focus.
6. Adjust object in the field.
7. Regulate the light.
8. Study the object.

After Study.

1. Raise objective (in case of higher power).
2. Remove preparation from stage.
3. Remove eye-piece* and objective.
4. Move the stand back from the edge of the table.

CAUTIONS CONCERNING THE CARE AND USE OF THE MICROSCOPE.

1. Never touch a lens with your fingers.
2. To remove dust from the lens, gently wipe it with a clean rag of soft, worn linen. If this is not successful, blow your breath on the lens and wipe it again.
3. To remove balsam, or other adhesive substances from a lens, a drop of alcohol, turpentine, or benzol is necessary, but the young student should not attempt to use it. He should promptly submit the lens to the instructor.
4. Lenses when not in immediate use should be protected against dust and injury, and all parts when stored should be protected against moisture and the action of chemicals.
5. In a microscope having its adjustment by means of sleeve and sliding-tube, the latter should be frequently cleaned with vaseline, or other mineral oil, to keep it in good working order.

* The eye-piece may remain in the tube.

6. The fine adjustment sometimes fails. In such a case, it is likely that the screw attached to the milled head has been run to its limit and must now be turned back.
7. Never focus downward *while looking in the tube,* unless the object is already in sight. If the objective must come nearer to the object, you should watch the movement from the outside, in order to protect both the objective and the preparation against accident.

THE HAND MAGNIFIER.

(*a*) Take your hand lens, usually called a magnifier, and look at printed letters as you did with the low-power objective. Now look at the back of your hand. When you use a magnifier, you should turn the object so as to let the light fall directly on the exact spot which you are trying to see.

(*b*) Take a small piece of cardboard, on which a series of about a dozen fine black lines have been drawn parallel, say about a sixteenth of an inch apart, and about two inches long, and lay it on the table. Now get a careful focus on the middle of this band of lines, and while the eye is observing the magnified space between two adjacent lines, it can also see along the side of the lens and observe the real spaces between lines. Compare the magnified spaces with those outside. How many spaces outside are subtended by, or are required to reach across, one of the magnified spaces ? This shows you the magnifying power of your lens. For example : if one magnified space seems as wide as three spaces really are, the lens has a magnifying power of three diameters, which is written thus, $\times 3$.

(*c*) Get the magnifying power of other lenses. Now take your low-power objective, and, using it as you did the hand lens, find its magnifying power and write it.

SIGNS AND SYMBOLS EMPLOYED.

m = use hand magnifier.

lp = use lower power of microscope, forty to 150 diameters.

hp = use higher power of microscope, 150 to 350 diameters.

× 2, × 3, × 4, *etc.* = enlarge sketch 2, 3, 4, etc., diameters of the natural size of the object.

del. = 2′, 3′ 4′, etc., make a sketch having its largest diameter 2 inches, 3 inches, etc.

♂ = male.

♀ = female.

STUDY I.

A STUDY OF AN AMŒBA.

AMŒBA PROTEUS.

As an example of a unicellular type of animals.

Material Required. — (1) Living Amœbæ; (2) preparations of stained Amœbæ; (3) preparations showing stages in reproduction.

Habitat.

The Amœba* is an aquatic, microscopic animal, rarely large enough to be seen without the aid of a microscope. Amœbæ may be found throughout the entire year, but are found most readily in summer, in standing water, attached to submerged plants, and in the mud at the bottom. A few fragments of such plants and a little ooze scraped from the bottom and placed in an aquarium jar will be quite likely to yield an abundance of Amœbæ in a few weeks, although they may not seem to be present at first.

LABORATORY WORK.

A.—GENERAL APPEARANCE AND STRUCTURE.

(*a*) Note the form and general appearance of the Amœba (*lp*). Make a sketch (*hp*).

(*b*) Carefully observe the form of the outline (*hp*) and note any projections (**pseudopodia**) of the body substance (**protoplasm**).

(*c*) If any pseudopodium is changing its form, carefully note the result. What use (**function**) do you attribute to the pseudopodia? See whether you can verify, or prove this use. How?

* Any large species of Paramæcium may be substituted for Amœba in this study. A culture may be made in a few days by allowing fresh animal or vegetable tissue to decay in water. The "lily-pad" gives an excellent culture.

(*d*) By means of careful focusing (*hp*) observe the structure of the protoplasm. Is it of uniform appearance (**homogeneous**) in different regions?

(*e*) Can you find a small body (**nucleus**) which is denser than the surrounding protoplasm (*hp*)? Where is it located?

(*f*) Can you find one or more spots (**vacuoles**) which are clearer or less dense than the surrounding protoplasm? Make a sketch (*del.* 1½′) representing the Amœba with nucleus and vacuoles.

(*g*) Carefully examine the protoplasm along the edge (**ectosarc**) of the body and pseudopodia to determine whether it is clearer or denser than the interior protoplasm (**endosarc**). Which is the more homogeneous? In your last drawing indicate by a faint line the boundary between ectosarc and endosarc.

(*h*) Examine the interior, or endosarc of the Amœba body by carefully focusing a little lower than the surface or ectosarc. Can you find small particles (**food particles**) which are evidently not protoplasm? Represent these in your sketch.

B.—CONCERNING ORGANS AND FUNCTIONS.

(*a*) Have you found any structures or parts (**organs**) in the Amœba which you infer are used in performing a particular work, or function? If so, name them. How do you suppose this little animal (**animalcule**) performs the function of moving from place to place (**locomotion**)? Of taking food (**prehension**)? Of digesting its food (**digestion**)? Of breathing, or getting oxygen and eliminating carbonic acid gas (**respiration**)? Of feeling (**sensation**)?

(*b*) If possible observe an Amœba undergoing division (**fission**) and by this process forming two new Amœbæ

as a second generation. In the process of forming a new generation (**reproduction**) what became of the parent Amœba? Has there been a natural death?

(*c*) If possible trace the Amœba cell through its entire process of self division, and make sketches at intervals showing the successive stages.

(*d*) Amœba is the simplest form of an animal body and is a single unit of structure (**cell**). All higher animals are composed of an aggregation of more or less modified cells.

(*e*) Make careful drawings on your drawing-tablet of an Amœba and the various stages in its reproduction.

(*f*) Write up a description of the Amœba from your notes and sketches.

OTHER WORK.

1. Characteristic properties of protoplasm.
2. Essential elements and nature of a typical cell.
3. The general functions performed in the animal body.
4. Characteristics of Gregarina, Paramœcium, Foraminifera, and Vorticella.
5. Comparison of Amœba with other forms of Protozoa with reference to morphology, physiology, and habits.
6. The parasitic habit of Gregarina and the nature of a parasitic animal.
7. The characteristics and the classes of Protozoa.

References. — 20 — 22 — 24 — 27 — 31 — 38 — 43 — 44 — 52 — 62 — 79 — 80 — 87 — 88 — 89 — 91 — 106 — 116 — 120 — 122 — 123 — 124 — 126 — 129 — 140 — 150.

STUDY II.

A STUDY OF A FRESH-WATER SPONGE.

SPONGILLA (*Sp.*).

As a type of unicellular animals associated in a colony.

Material Required.—(1) Living specimens; (2) preserved material; (3) preparations of the amœboid cells; (4) preparations of spicules; (5) preparations of gemmules.

Habitat.

Spongilla, the fresh-water Sponge, consists of a mass, or colony of microscopic cells, or animals, supported in position by a skeleton of spicules. The colony may be readily seen by the unaided eye, and is found in streams, lakes, ponds and in reasonably clean ditches. It is attached to permanent floats or rafts, submerged boards, rocks and plants, and may be found at any season of the year. Colonies containing gemmules should be collected late in the fall or during the winter.

LABORATORY WORK.

GROSS AND MINUTE STRUCTURE.

(*a*) Note the general appearance of the living or preserved Sponge (*m*). Sketch.

(*b*) Examine a mass of Sponge (*m*) and note the structure. Is there a definite arrangement of the needle-like rods (**spicules**) which project beyond the mass?

(*c*) Take a small mass of living Sponge, crush it on a glass slip and examine it under a microscope (*lp*). Note the mass of cells (**sponge-flesh**) and the spicules, which constitute the supporting frame work (**skeleton**). Sketch.

(*d*) Examine the sponge-flesh (*hp*) and note the form of the cells composing it. Do they adhere firmly to one another? Do you find a nucleus? In what respect do these cells (**amœboid elements**) agree with or differ from the Amœba? Sketch one or more amœboid elements.

(*e*) Examine the spicules (*hp*) and note their shape and structure. Sketch.

(*f*) In a mass of Sponge gathered in winter observe (*m*) the small seed-like structures (**gemmules**) found among the spicules. Sketch.

(*g*) Examine a gemmule (*lp*) and note the small, peculiarly shaped spicules (**amphidiscs**) upon its surface. Sketch gemmule and amphidiscs, and give a description.

(*h*) If possible determine the interior structure of the gemmule, and describe and sketch.

(*i*) Make a careful drawing of a Sponge colony containing gemmules with amphidiscs, also drawings of amœboid cells and spicules.

(*j*) Write up a description of the fresh-water Sponge from your notes and sketches.

OTHER WORK.

1. The anatomy of the Sponge colony.
2. Specialization of cells and a physiological division of labor.
3. Non-sexual reproduction and the simplest form of sexual reproduction by two specialized cells.
4. Comparison of the Sponge with Amœba.
5. The character of calcareous, horny, and siliceous Sponges.
6. Source, preparation, and use of the Sponge of commerce.
7. The characteristics and the classes of Porifera.

References. — 22 — 24 — 31 — 34 — 44 — 80 — 85 — 88 — 89 — 120 — 122 — 129 — 140 — 141 — 150.

STUDY III.

A STUDY OF A FRESH-WATER HYDRA.

HYDRA FUSCA.

As a type of a true multicellular animal in its simple gastrula form.

Material Required.—(1) Living and preserved specimens; (2) preparations of the entire Hydra; (3) preparations of transverse and longitudinal sections; (4) preparations of teased tissue.

Habitat.

The fresh-water Polyp, or Hydra, may be found in reasonably clean ditches, ponds and slowly moving streams. It is a small animal with a body about a quarter of an inch in length, and is usually attached to twigs or weeds, notably the duckweed (*Lemna*), and water-weed (*Anacharis*). Hydra may be collected from early spring until winter and kept indefinitely with proper care, in aquarium jars. Two species of Hydra are abundant, *H. fusca* and *H. viridis*, the former being of a brownish color and the latter of a green color and smaller than *H. fusca*. Either species may be used in this study.

LABORATORY WORK.

A.—GENERAL EXTERNAL CHARACTERS.

(*a*) Observe a live Hydra in a glass tumbler or aquarium, after it has been for some time attached to a weed or the side of the vessel, undisturbed. Note its general form, size, color, etc. Sketch (× 4).

(*b*) Note any movements that you can observe, and the different forms which the animal assumes. Now, with a fine wire or bristle, gently touch one of its arms and

note the result. What do you infer concerning the function of these arms?

(*c*) If the Hydra is not in a favorable position for study, it may be removed to a watch glass or glass slip into a few drops of water, protected from pressure of the cover-glass in the latter case. A permanent preparation may be used instead. Note more carefully the form of the body (*m* or *lp*). Compare the attached end or foot (**proximal end**) with the opposite (**distal**) end of the body, and note the differences.

(*d*) Note the circle of arms (**tentacles**) at the distal end of the body; their arrangement, number, shape.

(*e*) Note the form of the distal region of the body (**hypostome**) above the base of the tentacles. At the tip of the hypostome, under favorable conditions, may be seen a small opening (**mouth**) leading into the digestive cavity.

(*f*) Observe whether there is a bud or young Hydra attached to the body of the adult. Note also any slight thickening or elevation (**spermary**) from the surface of the Hydra in its distal region, or any similar structures (**ovary**) more nearly in the middle region of the body. If these structures are present, represent them in your former sketch.

(*g*) In a permanent preparation, examine the surface of the body-wall (*hp*) and sketch a small region. Do the same for one of the tentacles.

B.—INTERNAL STRUCTURE.

(*a*) Examine a transverse section through the proximal region of the body (*lp*). Note the large central digestive cavity (**enteron,** or **primitive alimentary canal**).

(*b*) Examine the body-wall and note the number of cell-layers (*lp*). Note the general appearance of the outer

layer of cells (**ectoderm**), and also of the inner (**endoderm**) layer. Which is the thicker layer?

(*c*) Can you find a trace of a very thin layer (**mesoglea**, or **supporting lamella**) between the ectoderm and endoderm (*lp*)? Make a diagram of the section, (*del. 1'*) showing the relative thickness of the different layers of cells.

(*d*) Examine a preparation of a longitudinal section through the middle of the body (*lp*). Make a diagram (*del. 2'*), representing the proper proportions of the enteron and cell-layers.

(*e*) Examine the cells of the ectoderm (*hp*) and note their form, structure, etc. Do you find their nuclei? Can you find more than one kind of cells in the ectoderm? Sketch a small region of cells.

(*f*) Examine the cells of the endoderm and describe them. Sketch.

(*g*) Examine a section through an ovary (*hp*). Note the peculiar form of the cells. Compare these (**ovarian cells**) with the typical ectodermal cells. Sketch.

(*h*) Among the ovarian cells, try to find one (**ovum** or **egg**) much larger than the others, and note its peculiar form and structure. What does this ovum resemble? Sketch.

(*i*) Examine a section through a spermary (*hp*) and note the peculiarity of the cells. Sketch.

(*j*) Examine a preparation of ectoderm with the cells teased out (*hp*). Note a kind of cell (**interstitial cell**) much smaller than the typical ectodermal cell. Observe a small, pear-shaped body (**nematocyst**) occurring among both ectodermal and interstitial cells. Sketch.

(*k*) Make careful drawings of the principal structures studied in Hydra.

(*l*) Write up a description of the form and structure (**morphology**) of the Hydra, from your notes and sketches.

OTHER WORK.

1. The significance, in Hydra, of the remarkable powers of recovery from injury.
2. The specialization and functions of ectoderm and endoderm.
3. Specialization of ectodermal cells in structure and function.
4. Demonstration of the simplest form of muscular and nerve cells.
5. The two-fold method of reproduction, and a comparison of each with reproduction in Amœba and Spongilla.
6. Comparison of Hydra with types already studied.
7. The general morphology of the Hydrozoa colony, Coral Polyp, Sea-anemone, and Physalia.
8. The relation between Hydra and other forms of the group.
9. The characteristics and the classes of Cœlenterata.

References. — 20 — 22 — 27 — 31 — 34 — 43 — 44 — 62 — 79 — 80 — 85 — 88 — 89 — 91 — 106 — 116 — 120 — 124 — 126 — 129 — 140 — 150.

STUDY IV.

A STUDY OF A STAR-FISH.

ASTERIAS VULGARIS.

As an example of the radial or Echinoderm type.

Material Required.—(1) A set of dried specimens; (2) a supply of alcoholic specimens; (3) one or more injected specimens; (4) some carefully dissected preparations; (5) preparation of the hard parts; (6) transverse sections of a ray and other microscopical preparations of tissues.

Habitat.

The Star-fish belongs to a group of animals which live only in salt water. It may be found abundantly in certain localities, notably in the oyster and clam beds along the coast, or attached to wooden piers and rocks below the surface of the water. The Star-fish, known among fishermen as the "five-finger," is the principal enemy of the oyster and clam along the coast, and is a great obstacle to successful oyster culture.

LABORATORY WORK.

EXTERNAL MORPHOLOGY.

A.—GENERAL FORM AND TOPOGRAPHY.

(*a*) Note the general form of the animal. How many and what are the principal regions or parts of the body?

(*b*) Note that if each arm (**ray**) were cut off at its base a central portion (**central disc**) would remain.

(*c*) Note the consistency of the body-wall (**perisoma**) and the character of its surface.

(*d*) Can you identify a head (**anterior**) region, and an opposite (**posterior**) or tail region in this animal?

(*e*) Examine and compare the upper (**aboral**) and lower (**oral**) surfaces, or aspects.

(*f*) On the central disc of the aboral surface, note a wart-like structure (**madreporite**). Observe its structure (*m*) and sketch (× 4).

(*g*) Note that the madreporite is located near the angle of two adjacent rays (**interradial angle**). How are the other rays arranged with reference to the madreporite?

(*h*) Observe that one ray (**anterior ray**) is located directly opposite or across the central disc from the madreporite. The anterior ray, together with the two adjacent rays to the right and left of it, constitute the *trivium*, the adjacent ones being designated respectively as the *right* and *left* rays of the trivium. The rays adjacent to the madreporite constitute the *bivium*, and are designated in a similar way. Now make a diagram (*del.2'*) representing the central disc, the rays and madreporite, and indicate the bivium and trivium, and name all the rays.

(*i*) Where could you cut the Star-fish so as to divide its body into two similar halves? Represent this by a dotted line in your diagram.

B.—STRUCTURES OF THE ABORAL SURFACE.

(*a*) Note the hard projections (**spines**) distributed over the surface. Any hard substance developed in or upon the skin of an animal may be regarded as an external skeleton (**exoskeleton**). Can you detect any definite plan in the arrangement of the spines? What do you suppose is their function?

(*b*) Note the shape and structure of the spines (*m*). Are they all alike? Sketch several (× 5).

(*c*) Examine the surface between the spines (*m* or *lp*) and look for soft, tapering projections (**aboral tentacles**). Sketch.

(*d*) At the base of the spines (*m*) look for small, hard, pincer-like structures (**pedicellariæ**). With your forceps pinch off a few and examine them under the microscope (*lp*). Of how many parts does a pedicellaria consist? Sketch (× 10). What do you infer concerning their function?

C.—STRUCTURE OF THE ORAL SURFACE.

(*a*) Examine the oral surface. Note the deep, wide middle groove (**ambulacral groove**) which extends along each ray.

(*b*) Note the area of membrane (**peristome**) in the central region of the oral disc, and the central opening, *mouth*, through this membrane.

(*c*) How are the inner (**proximal**) ends of the ambulacral grooves related to the peristome? Where do the outer (**distal**) ends of the ambulacral grooves terminate? Make a diagram of the peristome and ambulacral grooves.

(*d*) Note the numerous flexible structures (**ambulacra**, or **tube feet**) in the ambulacral groove (*m*), and observe their structure. Sketch an ambulacrum (× 5).

(*e*) Observe how the ambulacra are arranged in the grooves? Describe their arrangement and indicate it by a diagram (× 5).

(*f*) Note the spines along the edge of the ambulacral groove. In what respects do they differ from the spines in other regions? Represent them in your last sketch.

(*g*) Note a whitish, thread-like structure (**radial nerve**) extending along the middle of the groove (*m*), and a similar structure (**nerve ring**) along the inner edge of the peristome. How are the radial nerves and the

nerve ring related? Where are the distal ends of the radial nerves? Make a diagram (*del. 2'*) of the nerve ring and radial nerves.

(*h*) Trace a radial nerve to its distal end at the tip of the ray (*m*) and observe that it terminates near the base of a median tentacle (**terminal tentacle**). At the base of the terminal tentacle (*m*) note a yellowish elevation (**eye-spot**).

(*i*) Make two outline drawings, natural size, one of the aboral and the other of the oral aspect of the Star-fish.

(*j*) Write up a description, from your notes and sketches, of the external morphology of the Star-fish.

INTERNAL MORPHOLOGY.

D.—THE BODY CAVITY.

(*a*) With your scissors carefully cut a small opening through the perisoma on the aboral surface near the distal tip of the anterior ray. Into this opening insert the point of one of the blades of your scissors and carefully cut through the body-wall along one side of the ray to the inter-radial angle. Now return to the point of beginning and cut the opposite side of the ray in the same manner. You are now ready to begin study of the shape, position and relations of the internal organs (**anatomy**).

(*b*) Note the space (**cœlom,** or **body cavity**) within the body wall which has now been laid open.

(*c*) Gently lift the loosened flap of the perisoma and note whether it is free or attached along its inner surface. Turn it back over the central disc, and note a pair of elongated, branched, greenish-brown bodies (**hepatic cæca**). Where are they attached?

(*d*) Note that each cæcum is held in place by a thin membrane (**mesentery**). Is the membrane single or double? Make a diagram of the hepatic cæca of this ray.

(*e*) Examine more carefully the structure of a cæcum (*m*). Sketch a small portion.

(*f*) Extending longitudinally along the middle line of the inner surface of the aboral wall of the ray, note a yellowish band (**extensor muscle**). Examine a small piece of it under the microscope (*hp*). What do you suppose is its function?

(*g*) Open the two adjacent rays in the same way as you did the first. Now, with your scissors, carefully cut the body-wall across the inter-radial angles and turn back the cover of the three open rays and central disc. Observe a small duct (*m*) or membranous tube leading from the proximal end of each cœcum and uniting with its fellow in a common larger duct (**pyloric duct**). Can you demonstrate that the pyloric duct leads into a central sac? Use blow-pipe and tipped bristle.

(*h*) Just below the pyloric duct observe a membranous lobe (**cardiac pouch**) which extends a short distance back into the ray and opens into a central digestive cavity (**stomach**). Demonstrate that it is connected with the stomach. Can you find a cardiac pouch in the adjacent ray? What do you think is the function of the cardiac pouch?

(*i*) Carefully trace the digestive tube (**alimentary canal**) from the mouth on the oral surface to the aboral surface of the central disc. Use blow-pipe and tipped bristle. Note the variations in the size of the alimentary canal in its different regions,—the spacious region (**stomach**) just beyond the mouth, the *pyloric sac*, and the minute slender portion (**intestine**) near the aboral

wall. Try to locate the very small terminal opening (**anus**) from the intestine. Make a diagram (*del.* 2′) to represent the alimentary canal, including its general form, regions and openings.

(*j*) In the floor of a ray look for two elongated branched structures, the reproductive organs (**gonads**), somewhat similar in appearance to the hepatic cœca, but during the spawning season much more conspicuous. Where are they attached? Are the two lobes of the same ray connected? Are those of the adjacent rays connected with each other? Where are their proximal ends attached? Sketch (× 3).

(*k*) Examine a gonad more carefully (*m*) and sketch a small portion.

(*l*) Along each side of the median ridge in the floor of the ray note a series of thin-walled sacs (**ampullæ**). How are they arranged (*m*)? Make a diagram (× 5) of a small patch showing their arrangement.

(*m*) Ascertain whether there is any relation between the ampullæ in the cœlom and the ambulacra in the external groove. Use blow-pipe and tipped bristle.

(*n*) Observe the hard parts (**ossicles**) constituting the floor of the ray and note (*m*) their form and relation. Make a sketch of a small portion of the floor, including a region of the median ridge, to show the form and relation of the ossicles and the relative position of the ampullæ.

(*o*) Study the end of a transverse section of the floor of a ray. Note (*m*) the cut end of a small tube (**radial water-tube**) extending above the radial nerve. Sketch the transverse section (× 4).

(*p*) Examine a preparation of a transverse section of a small ray (*lp* or *hp*) and identify the various organs which

you have studied in the larger rays. Can you discover any connection between the water tubes, ampullæ, and ambulacra? Make an outline sketch.

(*q*) Make outline drawings of the most important internal structures. Write up a description from your notes and sketches of the anatomy of the Star-fish.

OTHER WORK.

1. Demonstration of the water-vascular system in Star-fish.
2. Demonstration of other systems of organs, with explanations of their functions.
3. The Star-fish as a bisexual animal; its reproduction and development.
4. Concerning the structure, composition, and development of the exoskeleton.
5. Concerning the power of restoring mutilated and lost parts.
6. Comparison of Star-fish with types already studied.
7. The general morphology of the Sea-urchin, Sand-dollar Synapta, and Sea-cucumber.
8. Comparison of the forms of this group.
9. Characteristics and the classes of Echinodermata.

References. — 22 — 24 — 31 — 34 — 44 — 80 — 85 — 88 — 91 — 104 — 116 — 120 — 122 — 124 — 129 — 140 — 145 — 148 — 150.

STUDY V.

A STUDY OF THE EARTHWORM

ALLOLOBOPHORA TUMIDA.

As a type of the Vermes or simplest forms of bilateral animals.

Material Required.—(1) Living earthworms; (2) a supply of alcoholic specimens; (3) a few dried preparations; (4) a set of preparations containing transverse sections through the most instructive regions of the body; (5) some egg-capsules; (6) preparations of setæ.

Habitat.

The Earthworm, or angleworm, is a very easily accessible animal, occurring everywhere in the soil near the surface, notably in gardens and heaps of old manure. The spring is the best time for collecting material intended for microscopical study; but for external study and dissection the worms may be collected at any time, and can be kept alive in pots or jars of loam, with proper care. The egg-capsules should be collected in the spring.

LABORATORY WORK.

A.—OBSERVATIONS UPON THE LIVING WORM.

(*a*) Take a living Earthworm, and after passing it through water to moisten its body, place it upon the laboratory table and observe its movements. Note its course. Does it always move with the same end of its body in advance? Can you discover by what means it is enabled to crawl? Note the course of its path on the table.

(*b*) Gently touch one end with your forceps, and note the result. Now touch the opposite end, and note the result. Which is the more sensitive?

(*c*) Observe a blood vessel visible through the body-wall (*m*), extending longitudinally along the middle line, and watch for its pulsation. Note the colors of the body.

B.—GENERAL TOPOGRAPHY AND EXTERNAL CHARACTERS.

(*a*) Examine an alcoholic or dried worm, and note the general shape of the body. Measure the exact length and greatest thickness of the body.

(*b*) Examine and compare the two ends of the body (*m*). Are they alike? Which do you regard the forward (**anterior**) end, and which the hinder (**posterior**) end of the body? Has the animal a head or tail? In what respects do the anterior and posterior ends differ?

(*c*) Which do you regard the lower (**ventral**) and which the upper (**dorsal**) surface of the animal? State your reasons. Are the dorsal and ventral surfaces exactly alike (*m*)? If not, in what respects do they differ?

(*d*) Imagine the animal divided vertically through the middle (**median**) line into right and left halves. Note that the two lateral halves are exactly alike (**bi-laterally symmetrical**).

(*e*) Observe that the body is composed of sections or rings (**somites**). Can you find them in every region of the body? Are they everywhere exactly alike?

(*f*) Note a thick band or girdle (**cingulum**) a little ways back of the anterior end of the body. Does the cingulum extend entirely around the body? Describe it. Over how many somites does it extend? Sketch ($\times$ 2) the

cingulum, including three somites immediately in front, and the three just back of it.

(*g*) Examine the first entire somite at the anterior end of the worm (*m*). In front of the first somite note a pointed lip or lobe (**prostomium**). Is it attached principally to the dorsal or ventral region of the first somite? Sketch (× 2) the anterior end of the animal, dorsal view, including the prostomium and first ten somites.

(*h*) Below the prostomium observe a small opening, *mouth*, which perforates the first somite.

(*i*) Observe the *anus*, a slit-like opening at the posterior end of the body. Does it extend up and down (**dorso-ventrally**) or from side to side (**laterally**)? Note the shape of the last somite and the form of the posterior end of the worm. Make a sketch (× 2) of the posterior end of the animal, including the last ten somites.

(*j*) Make an accurate count and note the number of somites in front of the cingulum, the number occupied by the cingulum, the number back of the cingulum, and state the total number in the worm.

(*k*) Carefully examine the surface of the body (*m*) to detect small bristle-like ***exoskeletal*** structures (**setæ**) implanted in the body-wall and projecting a little distance beyond the surface. How many setæ are there in each somite, where situated and how arranged? In what direction do they point? Can you find somites without setæ? What do you suppose is the function of the setæ? With your forceps remove a seta and examine it under the microscope (*lp*) and sketch. Make a diagram (× 2) of a somite and indicate the position and arrangement of the setæ.

(*l*) Observe the very delicate outer membrane (**cuticle**) which

covers the entire body. It is irridescent in the living worm, and readily removed after the dead specimen has been in water a few hours. Examine a small piece under the microscope (*hp*) and sketch its structure.

(*m*) Make a careful drawing of the Earthworm. Also make two enlarged drawings (× 2) of the anterior end, a dorsal and a ventral view, each including the first forty somites, also a drawing of the posterior end dorsal view, including the last ten somites, and one of a seta.

(*n*) Write up a description of the topography and external structure.

C.—GROSS ANATOMY.

(*a*) Extend an Earthworm under water, dorsal surface upward, and fasten it down with pins. With fine pointed scissors cut through the body-wall along the median, dorsal line from end to end. Note the transverse, membranous partitions (**septa**) which, in general, correspond to the external markings of the somites and divide the cœlom into many chambers.

(*b*) With your forceps carefully lift the flap on the left side, and with a sharp scalpel cut the septa close along the body-wall. Now pin this flap back, and do the same for the right side.

(*c*) Note the *alimentary canal*, which is a straight tube extending from the mouth to the anus, and observe its modifications in different regions. Note the thin-walled enlargement (**buccal sac**) in the region of the first three somites; the thick-walled portion (**pharynx**) extending from the fourth to the seventh somite; the straight tube (**œsophagus**) extending from

the seventh to the twelfth somite; the abrupt enlargement (**crop**) extending from the twelfth to the sixteenth somite, and the similar one (**gizzard**) following and extending back to about the twentieth somite. Trace the remaining portion of the alimentary canal from the gizzard to the anal opening. Make a diagram showing the various regions of the alimentary canal and name them. Note the fibrous structures passing from the surface of the pharynx. Where are they attached and what do you suppose is their use?

(*d*) In a freshly killed animal which has not been in alcohol, observe a dark-red blood vessel (**dorsal vessel**) which extends from the hinder end of the body forward as far as the pharynx, over which it spreads in numerous branches. Observe that in one region the dorsal vessel gives off large swollen branches, so-called "*hearts*," in pairs (**lateral vessels**) which pass around the alimentary canal. How many pairs of lateral vessels can you find? Can you find any other branches given off from the dorsal vessel? Sketch (× 2) the dorsal vessel including its lateral branches.

(*e*) Back of the cingulum carefully remove a portion of the intestine, about an inch in length, to expose the organs below. With your pipette wash out this region with water and then in the same way wash it with seventy per cent alcohol. In a few minutes place the animal under water again and examine (*m*) the body cavity along the ventral and lateral surfaces of the body wall. Note the long, slender excretory tubes (**nephridia**) thrown into loops. How many are there for each somite? Is the nephridium uniform throughout its entire length? Sketch (× 20).

(*f*) In the median line, and extending longitudinally

along the floor of the body cavity, note a white thread-like structure (**ventral nerve-chain**). Observe (*m*) that there are at regular intervals slight enlargements (**nerve ganglia**) of the nerve. How often do they occur with reference to the somites? Sketch (× 2).

D.—MINUTE ANATOMY.

(*a*) Examine a transverse section of the animal (*lp*) through the intestinal region, placing the slide so that the dorsal view of the section shall extend away from you and the ventral view toward you. Observe the general outline of the section. Identify the body-wall, cœlom, intestine, dorsal vessel, lateral vessel, nephridia, and setæ.

(*b*) Note that the intestinal wall in one place makes a deep fold (**typhlosole**) into the intestine and thus narrows its cavity. In which region of the intestine is the typhlosole situated?

(*c*) In the ventral region of the cœlom note (*lp*) an oval-shaped structure, ventral nerve-chain, with large cells (**nerve cells**) containing distinct nuclei.

(*d*) Between the nerve-chain and intestine, note a blood vessel (**ventral vessel**). Compare its size with that of the dorsal vessel. Make a careful diagram (*lp*) representing in outline all the structures in this section which you have identified (*del. 2'*).

(*e*) Examine a favorable portion of the body-wall (*hp*) and note the number of cell layers and their arrangement. Note that the cells of each region are alike and intimately connected (**tissue**) and have apparently the same function. Observe the outer, thin, structureless layer, *cuticle*, and next to it the layer of columnar cells (**epidermis**) set side by side at right angles to

the surface of the body. At which end of these cells are their nuclei? Note next a layer of tissue somewhat thicker than the epidermis (**circular muscles**) with long fibers extending around the body; also the inner thicker layer (**longitudinal muscles**) whose fibers extend longitudinally to the body and are arranged in sheets, the cross sections of which have a feathery appearance. Make a drawing of the body wall showing the different cell-layers (*del. 1'*).

(*f*) Examine an egg capsule (*m*) and make two sketches, one of natural size and the other enlarged (× 5).

(*g*) Study a preparation of the contents of a newly-laid capsule (*hp*) and observe the large spherical reproductive (♀) bodies, *ova*, and the minute, lash-like reproductive (♂) structures (**spermatozoa**). Sketch.

(*h*) Examine a preparation (*hp*) of the contents of an older capsule, and observe that instead of ova there are young Earthworms, more or less developed (**embryos**). Sketch.

(*i*) Write a description of the gross and minute anatomy of the Earthworm, and make drawings of the principal structures included in this study.

OTHER WORK.

1. Demonstration of the digestive, circulatory, excretory, sensory, and reproductive systems in the Earthworm.
2. Habits of the Earthworm, and its relation to the soil.
3. Tapeworm, Trichina, Pasteworm, and Leech compared.
4. Degenerate condition of organs in parasitic animals.
5. The life-history of the Tapeworm, or of the Liver-fluke.
6. The characteristics and the classes of Vermes.

References. — 22 — 27 — 31 — 34 — 41 — 43 — 44 — 62 — 79 — 80 — 85 — 88 — 91 — 106 — 116 — 120 — 122 — 124 — 126 — 129 — 137 — 140 — 150 — 156 — 166.

STUDY VI.

A STUDY OF A CRAYFISH.

CAMBARUS IMMUNIS.

As a type of the Arthropoda or animals, showing more or less distinctly marked body regions and segmented appendages. An example of the crustacean type.

Material Required.—(1) Living Crayfishes; (2) a supply of alcoholic material; (3) a few prepared exoskeletons of the Crayfish; (4) a prepared exoskeleton of the Lobster; (5) Carefully dissected preparations of the Crayfish and Lobster; (6) Injected preparations of the Lobster or Crayfish; (7) microscopical preparations of tissue.

Habitat.

The Crayfish is found in salt and fresh water. It is most accessible in ditches, along streams, in shady places and in low moist ground where it can reach water by burrowing a few feet below the surface. Its favorite hiding place is under stones lying near the edge of streams and in shallow water.

LABORATORY WORK.

A.—OBSERVATIONS UPON THE LIVING CRAYFISH.

(*a*) Study a living Crayfish in a tray of water and note its method of locomotion. By what method does it move forward? How many and which pairs of legs are employed? How does it move backward? Explain the process. In which direction can it move most rapidly?

(*b*) Frighten the animal by suddenly thrusting your hand toward it from in front and note the result. Now

slowly move your pencil toward one of its large claws and note its action. Touch one of its long "horns." What do you infer concerning their function?

(*c*) With your forceps turn the animal on its back, upon the table, and note the result. In what way can you pick up the Crayfish with your fingers so that it cannot defend itself?

EXTERNAL MORPHOLOGY.

B.—THE GENERAL FORM AND REGIONS OF THE BODY.

(*a*) Note the general form of the body as seen from the dorsal aspect. Into how many principal regions is it distinctly marked?

(*b*) Note the anterior region (**cephalo-thorax**) including the head and anterior body region with a continuous dorsal shell (**carapace**) covering. Note the posterior body region (**abdomen**), protected by a number of ring-like covers, one for each somite.

(*c*) Observe a more or less distinct transverse line or groove (**cervical groove, or suture**) which marks the carapace into two regions, the anterior (**cephalic**) or head region, and the posterior (**thoracic**) region. Trace the posterior and ventral edges of the carapace and note whether they are free or attached to the body.

(*d*) Note the forward projection (**rostrum**) of the carapace, between and above the eyes. Make a careful sketch of the carapace, representing the cervical suture and rostrum.

(*e*) Of how many somites is the abdomen composed? Bend and straighten the abdomen and note how the edges of the somites fit upon each other.

(*f*) In the last somite (**telson**) on its ventral aspect, note a longitudinal slit, the anal opening. Sketch the abdo-

men as seen from the dorsal aspect, representing nothing but the somites.

(*g*) Examine the shape of the third abdominal somite, tracing it entirely around the body. Note the shape of the dorsal portion (**tergite**) of the somite shell; its lateral parts (**pleurites**); its ventral part (**sternite**). Note that the ventral edges of the pleurites end as scallops. Do all the pleurites terminate in this way? Sketch the left lateral view of the entire body, omitting the appendages, and number the abdominal somites from the thorax back.

C.—THE THORACIC AND ABDOMINAL APPENDAGES.

(*a*) Note the filament-like appendages (**swimmerets**) on the abdomen. Where on the somites are they located? How many for each somite? How many pairs in all? Which somites, if any, have no swimmerets?

(*b*) Examine carefully the swimmerets on the third somite (*m*). Note the stalk of the swimmeret, or proximal portion (**protopodite**) and its two branches, an outer branch (**exopodite**) and an inner (**endopodite**). Sketch (× 2).

(*c*) Compare the swimmerets of different somites. Are they all alike? Describe any differences in appearance.

(*d*) Examine the distal end of the abdomen (**caudal fin**). Spread out the caudal fin and note the plan of its parts. Note the number and how the parts arrange themselves in folding. What is the function of the caudal fin? Sketch (× 2).

(*e*) Note the large appendages of the thorax. How many pairs are there? Examine the first having large jaws (**chelæ**) and note the number of pieces (**segments**) of which it is composed. Note in how many places the

segments unite to form joints (**articulation**). Sketch one of these appendages (**chelapeds**), carefully representing all the segments and articulations (× 2).

(*f*) Examine one of the second pair of appendages and compare it with one of the first. Now compare it with one of the third pair and note the differences.

(*g*) Examine one of the fourth and fifth pairs and compare them with the preceding pairs. Sketch one of the fourth pair (× 2).

(*h*) Can you discover any similarity between the thoracic and abdominal appendages? If you imagine the two parts of the jaws, or pincers in the thoracic appendages as representing the exopodite and endopodite of the swimmerets, then which of these structures is not represented in the fourth and fifth thoracic appendages?

D.—CEPHALIC APPENDAGES—ORAL AND TACTILE.

(*a*) Note three similar pairs of appendages (**maxillipeds**) just in front of the large pincers, or chelæ (*m*). With your forceps, lift the first pair and ascertain the number of segments in each. Describe and sketch (× 2). Examine the other two pairs of maxillipeds and compare these with the first.

(*b*) Examine two pairs of thin appendages (**maxillæ**) in front of the maxillipeds (*m*). Sketch (× 2). Can you identify *exopodite* and *endopodite?*

(*c*) Note a pair of short, hard, toothed appendages (**mandibles**) in front of the maxillæ (*m*). Note that each mandible bears a jointed part (**palpus**). Sketch (× 2). Identify the *mouth* and describe its location.

(*d*) Note the long horn-like projections (**antennæ**) on the front of the head. Describe their location with ref-

erence to the rostrum. Examine their large basal segments. How many segments in each antenna? Of what do the antennæ consist? Sketch (× 2).

(*e*) Near the base of the antennæ, note a pair of smaller, similar appendages (**antennules**) How many branches altogether? Describe and sketch (× 2).

(*f*) Note the position of the eyes. What is peculiar concerning their attachment? Examine the stem or stalk upon which they are situated (*m*). With your forceps extend and retract the eye. Move it from side to side to determine its range of motion. Sketch (× 2). Examine the surface of the eye (*m*) and note the small spaces (**facets**) which are characteristic of compound eyes. Sketch a small portion to represent the facets.

(*g*) On the ventral surface of the basal segment of the antenna, note a whitish cone (*m*) containing a small opening from the excretory organs (**green-glands**).

(*h*) In the basal segments of each antennule, examine a small depression (**ear-sac**) having a thin membranous floor and beset by delicate setæ, or hairs. What external evidence is there of this structure being an ear?

(*i*) Make a drawing of a dorsal view of the Crayfish, first carefully arranging the appendages in a natural position. Write a description of the external morphology of the Crayfish.

INTERNAL ANATOMY.

E.—THE GILLS AND THE GILL CHAMBER.

(*a*) With the points of your scissors carefully cut through the carapace along the dorsal median line as far forward as the cervical suture and then down on the left side, and remove the left portion of the carapace.

Note the membranous lining and its extent, also the structure of the carapace and the fringe of setæ or hairs along its ventral edges.

(*b*) Observe the feather-like respiratory structures (**gills**) now exposed. Observe the region or space they occupy (**gill-chamber**) and the character of its inner wall To what are the gills attached and how arranged? How many sets of gills can you find? How many gills are there of each kind with reference to their place of attachment? Are the gills external or internal structures?

(*c*) Let some water flow over the gills so as to float them back into their natural position against the body. What is the natural course of the water through the gill-chamber in the living animal? Now make a sketch (× 2) of the gills attached to the left side of the body.

(*d*) Examine a microscopic preparation (*lp*) of a small gill and sketch it.

F.—THE HEART AND BLOOD VESSELS.

(*a*) Remove the right side of the carapace and pin the animal under water, dorsal surface upward. Begin at the first abdominal somite, and carefully cut through the body wall along each side of the abdomen backward to the telson, and remove the tergites. If the membrane lining the inner surface of the exoskeleton was left intact carefully remove it.

(*b*) Examine one of these tergites carefully and note its hard and elastic structure. The substance to which these properties are due (**chitin**) forms the hard parts of the Crayfish.

(*c*) In the dorsal region of the thorax, note a whitish oblong body (**heart**). The heart is the principal organ of

the circulatory system. Carefully move it from side to side to discover its points of connection. Note the cavity (**pericardial sinus**) in which it is suspended.

(*d*) *At the anterior end of the heart, note the connection of several small whitish tubes or vessels (**arteries**) which convey the blood away from the heart when the latter contracts.

(*e*) Note the large median tube (**ophthalmic artery**) which extends forward and sends branches to the eyes. Observe a pair of vessels (**antennary arteries**) which take their origin near the base of the ophthalmic, one on each side, and pass obliquely downward and forward to supply the antennæ. A short distance from their origin, the antennary arteries give off branches (**gastric arteries**) which supply the walls of the stomach with blood.

(*f*) At the posterior end of the heart, observe a large median blood vessel (**superior abdominal artery**) which passes back over the intestine and supplies the latter and adjacent regions.

(*g*) Examine the dorsal surface of the heart (*m*) to find a pair of valved slits (**ostia**), through which the blood enters the heart from the pericardial sinus. Can you find other ostia? Make a careful sketch (× 2) of the heart and arteries, naming the parts.

(*h*) Below the pericardial sinus, observe the reproductive organs, either spermary (♂) or ovary (♀). The spermary is a soft, white, three-lobed body; one lobe extending posteriorily and two anteriorly. Note at the
30 junction of the lobes a pair of coiled tubes (**sperm-ducts**) passing in a ventral direction. Sketch (× 2).

(*i*) The ovary is a structure somewhat similar to the spermary,

* The student should have access to an injected preparation.

excepting that its anterior lobes are situated more ventrally and that it may be relatively very large when the ova are nearly ripe. The tubes (**oviducts**) are straight and wider, and shorter than the sperm-ducts. Sketch ($\times$ 2). Can you find external openings of oviduct or sperm-ducts?

G.—THE ALIMENTARY CANAL.

(*a*) Remove as much of the muscles along the left side of the thorax as is necessary to expose the *alimentary canal.* Note the large muscles which lie in the abdomen, especially those (*extensor muscles*) which are situated above the alimentary canal. Observe that the alimentary canal is nearly a straight tube, extending through the entire length of the body.

(*b*) Identify the short, wide tube, *œsophagus*, extending vertically from the mouth to the spacious enlargement, *stomach*, which occupies the greater part of the head and extends a little ways into the thorax.

(*c*) Note that the stomach consists of two regions, an anterior (**cardiac chamber**) and a posterior (**pyloric chamber**) separated by a constriction or infolding of the wall. *Note that the stomach is lined by a firm layer of chitin, which in one region is developed into a complex mechanism (**gastric mill**) of prominent internal folds, and three hard, dark structures (**teeth**).

(*a*) Back of the pyloric chamber, observe (*m*) the brownish lobed body (**liver**) on each side of the alimentary canal. The liver is a digestive organ whose function is to secrete a liquid (**bile**) which flows through a tube (**bile duct**) into the intestine. Can you find the bile duct? Sketch ($\times$ 2) the liver and bile duct.

(*e*) From this point trace the intestine back to its external

* The student should have access to a dried preparation of the stomach of a Lobster.

opening, *anus*, in the telson. Make an outline sketch of the alimentary canal from a lateral view, naming all its parts.

H.—THE CENTRAL NERVE CORD.

(*a*) With your scissors cut off the intestine near the anus and carefully lift it to one side, removing it from its natural position as far forward as the œsopahgus. Observe the large white rolls of firm tissue (**flexor muscles**) which extend along each side of the median groove from which the intestine has been removed.

(*b*) Carefully press apart the two flexor muscles along the median line. In the floor of the abdomen along the median line, note the slender, white cord, *central nerve chain*, containing abrupt ganglionic enlargements. How many ganglia are there in the abdomen? Note the branches (**nerves**) given off along the sides of the ganglia to supply the muscles of this region.

(*c*) Trace the central nerve chain forward through the thorax carefully cutting away all the hard parts necessary to expose the nerve. Note the first large ganglion (**sub-œsophageal ganglion**) back of the œsophagus. From this ganglion trace two branches (**œsophageal collar**) which pass around the œsophagus, one on each side, and unite in a larger ganglion ("**brain,**" or **supra-œsophageal ganglion**) some distance in front of the œsophagus and near the base of the antennules. This ganglion gives off branches to the eyes, antennæ and antennules.

(*d*) Examine the ganglia situated in the thorax. How many are there? Can you find nerves given off to the thoracic appendages? Make a careful sketch (× 2) representing the central nerve chain, ganglia, nerve collar, and "brain."

(*e*) Examine an eye of the Crayfish, which has been for about five days in a .5% solution of chromic acid. Sketch it, including the eye-stalk. Strip off the clear cover (**cornea**) in front and examine it (*lp*), and note your observations.

(*f*) Tease up a portion of the distal end of the eye in dilute glycerine and examine (*lp*) it. Observe the elongated angular bodies (**crystalline cones**) which may be still continuous with spindle-shaped structures (**rhabdomes**). Where do you find the color cells (**pigment cells**)? Sketch a few cones and rhabdomes.

OTHER WORK.

1. A general view of the morphology and physiology of the Crayfish.
2. The life-history and habits of the Crayfish.
3. The biology of food.
4. The general morphology of the Lobster, Spider-crab, Hermit-crab, and Sow-bug.
5. The power in crustacea and lower groups of casting off mutilated parts and developing new ones.
6. A comparison of the forms of this group with reference to structure and habits.
7. Comparison of the crustacean type with types already studied.
8. The characteristics and the orders of Crustacea.

References. — 20 — 22 — 24 — 31 — 34 — 43 — 44 — 72 — 79 — 80 — 82 — 85 — 88 — 91 — 96 — 106 — 108 — 115 — 116 — 120 — 122 — 124 — 126 — 129 — 140 — 144 — 145 — 150 — 170.

STUDY VII.

A STUDY OF A GRASSHOPPER.

**CALOPTENUS SPRETUS.*

To present the type of arthropods which are organized for aërial respiration and flight. An example of the Insects.

Material Required.—(1) Live Grasshoppers; (2) a supply of alcoholic material; (3) a set of preparations of tissues; (4) several preparations of the hard parts; (5) carefully dissected specimens demonstrating the digestive system; (6) dissected specimens demonstrating the nervous system; (7) a series of stages in the development of the Grasshopper.

Habitat.

Grasshoppers inhabit nearly every section of the United States, and may be collected in abundance during the summer and fall of the year. The supply of material can be stored in alcohol and kept indefinitely and ready for use.

LABORATORY WORK.

EXTERNAL MORPHOLOGY.

A.—GENERAL APPEARANCE AND TOPOGRAPHY OF THE BODY.

(*a*) Note the general outline of the body, viewed from its dorsal aspect, also as seen from a lateral aspect.

(*b*) Of how many principal regions is the body composed? Identify the *head, thorax* and *abdomen.*

(*c*) Compare the general plan of the body with that of the Crayfish. Has the Grasshopper a *more* or *less* distinct head and neck?

* Any of the larger forms may be used instead of the species here named, and it is not important that the entire class be provided with the same species.

B.—THE HEAD AND ITS APPENDAGES.

(*a*) Observe the shape of the head. **Is it movable?** Make an outline sketch of the left view (×3).

(*b*) How many pairs of antennæ are there? Note their attachment. How many *segments* (*m*) in each antenna? Sketch an antenna (× 3). Compare the antennæ of the Grasshopper with those of the Crayfish.

(*c*) Observe the position and shape of the eyes. Examine (*m*) them to determine whether they are *compound* eyes. In general, are they like or unlike the eyes in the Crayfish, and in what respects? In your last sketch indicate the shape and position of the left eye.

(*d*) Just in front of the large eye observe (*m*) a very small eye (**ocellus**). This is a single (**simple**) eye. Has it a mate on the other side of the head? Can you find (*m*) any more simple eyes, or ocelli on the head? If so describe their position and say whether they are in pairs. Represent the ocelli in your sketch.

(*e*) In the lower part of the face, in front, observe a movable flap, the upper lip (**labrum**). Move it, observe its mode of attachment and its shape. Sketch the front view (× 3).

(*f*) Press the labrum up in front and with your scissors cut it off close to the head. Observe back of its natural position a pair of hard, sharp-pointed jaws, *mandibles*. Carefully pry them open with your forceps. In which direction do they move, laterally or longitudinally? Remove one, examine (*m*) its shape and make a sketch (× 3).

(*g*) Open the other mandible as far as possible and observe (*m*) a brown structure (**tongue**) a little ways back of the mandible. Identify the *mouth*.

(*h*) Examine the lower, posterior region of the head and

note a thin flap (**labium**) or lower lip. Move it and observe its shape. Note the pair of jointed appendages (**labial palpi**) attached to its base. How many segments (*m*) in each labial palpus? Remove it and sketch the posterior view of the labium with its palpi (× 3).

(*i*) In front of the lower lip observe (*m*) a pair of smaller jaws, *maxillæ*, and note that each consists of three parts: a curved, toothed structure, which is the maxilla proper, a spoon-shaped structure covering the maxilla, and a jointed part (**maxillary palpus**). How many segments in this palpus (*m*). Remove one of the maxillæ and sketch it, representing all its parts (× 3).

C.—THE THORAX AND ITS APPENDAGES.

(*a*) Observe the divisions of the thorax. How many are there?

(*b*) Examine the triangular anterior division (**pro-thorax**), situated just back of the head. Make an outline sketch of the lateral view (× 3).

(*c*) Observe the first, or anterior pair of legs. To which region of the thorax are they attached? Examine (*m*) one of the legs carefully and note the number of its segments.

(*d*) Begin at the body and note the shape and relative size of the segments. Examine (*m*) the short, thick segment (**coxa**) which moves upon, or articulates with the hard covering of the thorax; observe the next segment (**trochanter**). How does it compare in size with the first? Now compare the third segment (**femur**) with the first two. Compare the femur with the fourth segment (**tibia**) with reference to size, shape and structure.

(*e*) Examine (*m*) the remaining region (**tarsus**) of the leg. How many segments has it? Observe that one tarsus is provided with a pair of sharp hooks and others with soft pads or cushions. What do you suppose is the function of the hooks and pads? Make a careful sketch of the front view of this leg (× 3).

(*f*) Examine the middle division of the thorax (**mesothorax**). Carefully trace the boundary between this division and the hinder portion of the thorax (**metathorax**), beginning on the ventral surface. Sketch the left lateral view of the mesothorax (× 3).

(*g*) Examine (*m*) the pair of legs on the mesothorax, and state in what particular they differ from the first pair.

(*h*) On the mesothorax just above the coxa observe a small narrow opening (**spiracle**) which is guarded by a pair of lips and serves as a breathing pore. Represent it in your last sketch.

(*i*) Carefully examine the wings. Lift them and spread out those on the left side. How many pairs are there? To which division of the thorax are the first, or anterior pair attached? To which division are the posterior wings attached?

(*j*) Carefully note the shape and color of the left anterior wing. Examine (*m*) its structure. Sketch this wing (× 3).

(*k*) Study the posterior wings in the same way, and observe the system of thread-like ridges (**veins**) which constitute its framework. Spread out this wing, pin it and sketch.

(*l*) Compare the anterior with the posterior wing and note the principal points of difference. How are the two related when not in use? Do you think there is any difference in function?

(*m*) Examine the hindermost division or metathorax. Sketch the lateral view (× 3).

(*n*) Examine (*m*) the third pair of legs and identify all its segments. Compare them with the corresponding segments of the first pair. Sketch (× 3).

(*o*) What do you suppose is the function of the first and second pairs of legs? The third pair? What methods of locomotion has the Grasshopper?

D.—THE ABDOMEN AND ITS PARTS.

(*a*) Observe the general shape of the abdomen, and the shape and arrangement of its somites. Does the covering of each somite extend entirely around the body as one piece?

(*b*) Examine the broad triangular piece in the dorsal region next to the metathorax. This represents the first abdominal somite. Does it extend entirely around the body?

(*c*) In the side of this incomplete somite observe (*m*) a large crescent-shaped cavity (**auditory sac**) containing across its opening a delicate shiny membrane (**tympanum**), ear drum. Near the anterior edge of the auditory sac, observe (*m*) a spiracle.

(*d*) Examine the covering or *exoskeleton* of the second abdominal somite. Of how many pieces does it consist? Identify the *tergite*, *pleurite* and *sternite* as you did in your study of the Crayfish.

(*e*) How many abdominal somites has this Grasshopper? Carefully count the tergites, beginning with the first or incomplete somite. Now count the sternites.

(*f*) Along the ventral edge of the pleurites observe (*m*) a series of spiracles. In which somites do you find spiracles?

(*g*) Observe that the somites in the posterior region of the abdomen are much modified in shape. This modification varies with the sex. In the female the abdomen is more tapering than in the male, and ends in two pairs of curved spines (**ovipositor**) which when brought together form a channel through which the eggs are deposited into the ground. Of which sex is your Grasshopper?

(*h*) Make a careful sketch of the abdomen, left view, representing all your observations (× 3).

(*i*) What are the principal points of similarity and difference between the Crayfish and Grasshopper?

INTERNAL ANATOMY.

E.—CIRCULATORY AND REPRODUCTIVE ORGANS.

(*a*) Take a large Grasshopper, either alcoholic or fresh, and remove the wings. Pin the specimen dorsal surface up, on the bottom of the dissecting tray. Remove the dorsal portion of the exoskeleton by beginning with the eighth or ninth somite and carefully cutting through the hard covering forward along the left side of the body to the head, using sharp pointed scissors. Now return to the point of beginning and with your forceps lift the cut edge of the upper wall, and with the point of your scalpel carefully loosen the tissues attached to its inner surface, turn the flap to your right and pin it down. The organs should should be studied under water.

(*b*) Examine the *heart*, which is a dorsal tube similar in position to that of the Crayfish. How does it differ from the heart in the latter animal? Sketch.

(*c*) Observe (*m*) the row of white rounded bodies (**air-sacs**) along each side of the abdomen. The air-sacs are

likely to remain attached to the inner surface of the flap which has been turned back. Note the white branched tubes (**tracheæ**) connected with the air-sacs. How are the air-sacs and tracheæ related to the spiracles? Carefully remove an air-sac and a portion of a trachea and examine them under the microscope (*lp*). Sketch.

(*d*) If your specimen is a female, identify the *ovaries* which are likely to be quite prominent in the abdominal cavity. Note the shape (*m* or *lp*) and color of the ova. Sketch (× 4). Identify the *oviducts*, one on each side, leading to the ovipositor.

(*e*) Remove all the eggs on the left side, being careful not to injure the organs which lie below.

(*f*) In the lateral regions of the thorax observe the large white bundles of *muscles*. Note their direction on the the right side. What do you suppose is their function? With your forceps pull off a small bit of muscle, tease it out on a slide with your needles, and examine it under the microscope (*lp*). Sketch.

(*g*) Examine (*hp*) a permanent preparation of stained muscle. Note the fine thread-like structures (**muscle fibres**). Observe the more highly stained nuclei. Carefully focus upon a fibre and determine whether there are faint parallel markings across it (**striated muscle fibre**), or whether the fibre is without such *striæ*, or marks (**unstriated muscle fibre**). Make a careful sketch representing a few fibres with nuclei, etc.

F.—THE DIGESTIVE ORGANS.

(*a*) Clear away all the muscles in the thorax lying above or along the left side of the alimentary canal.

(*b*) Trace the digestive tube or alimentary canal, beginning at the anterior end. Observe the dark portion of the tube, *œsophagus*, passing up from the *mouth* and

curving backward. Note its enlargement, *crop*, in the prothorax.

(*c*) Back of the crop, note several spindle-shaped pouches (**gastric cæca**) which extend parallel with the digestive tube. Are the gastric cæca connected with the digestive tube? How many are there? Make an outline sketch of the digestive tube up to this point (×3) and develop it as you continue your study.

(*d*) Back of the gastric cæca, observe an enlargement, the true *stomach*. Through how many abdominal somites does it extend?

(*e*) Trace the *intestine* from the stomach to its external opening. Complete your sketch.

(*f*) Press the crop a little to the right and look for several clusters of small bodies (**salivary glands**) and note the small tube which connects them with the mouth. Sketch (×3).

(*g*) Write up your notes on the anatomy of the Grasshopper, and make careful drawings of the principal organs.

OTHER WORK.

1. The morphology and physiology of respiration and circulation in the Grasshopper.
2. Comparative review of the digestive and nervous systems in the Grasshopper and Crayfish.
3. Characteristics of the Moth, Beetle, Bee, Fly, etc.
4. The characteristics of Spiders.
5. The life-history and metamorphosis in insects.
6. Intelligence in insects and lower types of animals.
7. Relation of insects to plants and to other animals.
8. The characteristics and the orders of Insecta.

References. — 8 — 22 — 24 — 31 — 33 — 34 — 44 — 50 — 80 — 85 — 88 — 91 — 98 — 99 — 101 — 103 — 116 — 120 — 122 — 124 — 128 — 129 — 130 — 135 — 136 — 140 — 148 — 150 — 168.

STUDY VIII.

A STUDY OF A FRESH-WATER MUSSEL.

UNIO PLICATA.

As an example of the soft-bodied unsegmented Mollusk type.

***Material Required.**—(1) living mussels; (2) stock supply for dissection; (3) a set of transverse sections for gross anatomy; (4) a supply of shells; (5) a few injected specimens; (6) the young stages of the mussels; (7) microscopic preparations of tissues.

Habitat.

The Pond, or Swan Mussel is common in ponds, slow streams, and canals. It prefers a muddy or sandy bottom where it can sink until only the extreme posterior dorsal edge is exposed above the mud and sand. It is easily kept in the laboratory throughout the year. For observation and study the live Mussel should be kept in an aquarium containing several inches of clean sand in the bottom. A stock supply of live Mussels may be kept in a tub or tank and if the water is changed once or twice per week they will not suffer for the want of a constant flow of fresh water.

The Mussels intended for gross sectioning should be killed in an aqueous solution of 0.25 per cent. chromic acid in which they remain about forty-eight hours, and are then transferred to alcohol. Mussels intended for dissection may be killed by being put into cold water and slowly warmed to a temperature of about 70° C.

* Any species of Unio, Anodonta, or even the Quahog, will answer very well for this study. In the United States the general name for the Mussel is *Clam*.

LABORATORY WORK.

EXTERNAL MORPHOLOGY.

A.—THE TOPOGRAPHY AND GENERAL FORM OF THE SHELL.

(*a*) Observe the general shape of the shell. Note that one end, *anterior*, is more blunt than the other, *posterior*, end, and that one edge (**dorsal margin**) is thicker than the opposite (**ventral margin**). With the anterior end pointing away from you and the dorsal edge upward, sketch the outline of the dorsal edge and name the ends.

(*b*) Of how many pieces (**valves**) is the shell of the Mussel composed? How can you designate the valves with reference to their position?

(*c*) Determine which is the right and which the left valve. Make an outline sketch of the right valve and indicate the anterior, posterior, dorsal and ventral regions.

B.—THE OUTER SURFACE OF THE SHELL.

(*a*) At the dorsal margin observe a pair of elevations (**umbones,** or **beak**), one on each valve. Is the umbo nearer the anterior or posterior end?

(*b*) Between the umbones and extending back of them note a smooth band (**hinge-ligament**). How is the ligament related to the valves? What function do you attribute to the ligament?

(*c*) Note the markings (**lines of growth**) on the surface of the valves. Describe their origin and direction. What is the nature of these lines, and how do you suppose they are formed? Do you find any other surface markings? Describe them. Sketch the left valve and represent the umbo, lines of growth, etc.

(*d*) Observe the thin, horny membrane (**periostracum**) projecting along the ventral edges of the valves (*m*). Do you find the periostracum in any other region (*m*)?

(*e*) Note and describe the coloring of the valve. Make an outline drawing of the dorsal aspect.

C.—THE INNER SURFACE OF THE SHELL.

(*a*) *Place a Mussel in water sufficient to cover it and slowly warm to about 40° C. Raise the left valve, and beginning at the ventral edge, with the handle of your scalpel carefully free the membrane attached to the inner surface of the valve. Now cut through the tough bodies which are attached to the valves, one near the anterior and one near the posterior end of the shell.

(*b*) Note the character of the inner surface of the shell. Observe its texture and color.

(*c*) Note the form and structure of the hinge ligament. Press the valves together and then release them and note the result. What is the function of the hinge ligament? Examine its structure carefully to determine how it performs its function.

(*d*) In the anterior region of the dorsal edge of the right valve note an irregular projection (**hinge "tooth"**), and a little distance back of this structure note another of very different form. Can you find a mate for each of these structures on the left valve?

(*e*) Compare the anterior tooth (**cardinal tooth**) with the one farther back (**lateral tooth**). How do they differ? Are the mates of the cardinal teeth alike? Are those of the lateral teeth alike?

(*f*) What function do you attribute to the hinge teeth? Why? Sketch each pair.

(*g*) Near the anterior end of the valve, note a scar-like struc-

*In order to economize the time of the class, the instructor should prepare the Mussels in advance.

ture (**anterior adductor impression**) where a large muscle has been attached, and a similar one near the posterior end of the valve (**posterior adductor impression**).

(*h*) In each muscle scar observe (*m*) the circular markings, *lines of growth.* Sketch a muscle scar and show these lines.

(*i*) A short distance from the ventral edge and extending parallel with it, note a boundary line (**pallial line**). Where are the ends of this line? Sketch.

D.— THE STRUCTURE AND COMPOSITION OF THE SHELL.

(*a*) Take a piece of shell and examine (*m*) the broken edge. How many kinds of layers can you distinguish?

(*b*) Is the structure in each layer the same? Compare the relative thickness of the layers. Sketch the broken edge.

(*c*) Put a small bit of shell into a test-tube and add a few drops of acid (at the sink.) Note the result. What do you infer?

(*d*) Examine a shell which has been exposed to great heat, *i. e.*, burnt. What do you observe?

E.— EXTERNAL APPEARANCE OF THE BODY IN OPENED SHELL.

(*a*) In a specimen with the left valve removed, note the general appearance of the body. Note the character of the body-wall. Identify it in the different regions. Which side of the body is exposed?

(*b*) Note the whitish circular structures, one near the anterior (**anterior adductor muscle**) and the other (**posterior adductor muscle**) near the posterior end of the body. What corresponding structure did you find in the valves?

(*c*) What relation between these muscles and the muscle

scars do you infer? What function do you attribute to the adductor muscles?

(*d*) Note the flap of membrane (**left mantle-lobe**) which covers the left side of the body. With your forceps gently lift it by its ventral edge and trace and describe its free edge. Sketch the outline of the mantle and indicate the position of the adductor muscles.

(*e*) Note the right mantle-lobe. Is it anywhere attached to the left lobe? If so, where?

(*f*) Lift the edge of the right mantle and note the line of attachment to the shell. What is this boundary line?

(*g*) At the posterior end of the mantle note the fringed edges (**siphons**) of the mantle. How are the two mantles related in this region? Examine (*m*) the dark tips (**tentacular processes**) on the siphons. Sketch the siphons, representing the processes.

(*h*) With your forceps lift the left lobe and note the space (**pallial, or mantle cavity**) between it and the right lobe.

(*i*) Note how far dorsally the mantle is free from the body, or the extent of the pallial cavity.

F.—THE ORGANS LYING IN THE PALLIAL CAVITY.

(*a*) With your scissors carefully trim away the mantle along its line of attachment to the body, beginning at the anterior adductor muscle. Make a sketch locating the muscles and representing the course and position of the cut edge of the mantle. This cut edge represents the dorsal boundary of the pallial cavity.

(*b*) Note the membranous structures, *gills*, which are attached to the body along the dorsal region of the pallial cavity.

(*c*) Play a stream of water from your pipette upon the gills and cause them to float and separate so that you may

observe their exact form and relation. Observe their attachment and relation to the body. How can you designate them with reference to their position?

(*d*) With your forceps carefully lift the upper (**left outer gill**) and observe and note its size and shape? Which edge is attached and which edges are free?

(*e*) Lay the outer gill back and lift the lower (**left inner gill**) and note its size and shape. How are the two gills related? Now lay them into their natural position. Which is the larger, and in what directions? Make an outline sketch of them in their natural position.

(*f*) Examine (*m*) the surface of the outer gill and sketch a portion of it. Examine (*lp*) a microscopic preparation of cross sections of the gill. Sketch.

(*g*) Just below the anterior adductor, observe (*m*) a pair of small membranes (**labial palpi**, or **palps**). Move them slightly with your forceps, or play the pipette upon them and note their position, shape, and relation. Designate the palps as you did the gills.

(*h*) At the anterior end, how is each palp related to its mate on the other side of the body?

(*i*) Between the outer and inner palps, at their extreme anterior ends, search (*m*) for a small opening, *the mouth*. Insert bristle. What do you suppose is the function of the palps? Sketch the palps and indicate the position of the mouth.

(*j*) Observe the large firm structure (**foot**) lying below the left gills and palps. Note its shape and sketch its outline. Name the organs which you have thus far observed in the pallial cavity.

(*k*) Note that the part of the pallial cavity which extends from the base of the gills ventrally (**branchial chamber**) is more or less separated by the gills and

foot into several compartments. How many compartments in the region of the foot? How many back of the foot?

(*l*) Observe that at the posterior end of the gills the right and left mantle lobes meet and form a longitudinal partition through the siphon region. This partition thus forms an upper space or tube (**exhalent,** or **cloacal siphon**) and a lower (**inhalent,** or **branchial siphon**).

(*m*) Which siphon connects with the branchial chamber? Which connects with the cloacal chamber?

(*n*) In the cloacal siphon just back of the posterior adductor, note a small opening, *anus*.

(*o*) Make careful drawings of the different views of the valves and of the Mussel lying in the shell. Write a description of the Mussel as far as now studied.

**INTERNAL ANATOMY.*

G.—THE CIRCULATORY SYSTEM.

(*a*) In the dorsal region of the body, between the hinge ligament and the base of the gills, observe the outline of a longitudinal cavity (**pericardial cavity**) protected only by a delicate portion of the body wall. With your scissors carefully cut away this delicate membrane as far as the anterior ends of the gills and back to the posterior adductor muscle. This somewhat triangular opening exposes the pericardial cavity.

(*b*) In the central region of the pericardial cavity, observe the pale muscular *heart* consisting of three divisions of which two are readily seen. Examine first the elongated thick-walled sac (**ventricle**) lying in the

* The student should be impressed with the fact that although a valve or exoskeleton of the animal has been removed, yet his study up to this point has been external to the true body wall.

middle of the cavity. Note that it is somewhat conical, its smaller end extending forward and the larger bi-lobed end backward.

(*c*) Now observe a thin-walled, triangular sac (**left auricle**) having its apex connected with the lateral region of the ventricle and its base extending along the base of the gills. By carefully lifting the ventricle, a portion of a similar structure (**right auricle**) may be seen on the opposite side of the body. The auricles receive aërated blood from the gills and convey it to the ventricle, which in turn by its contraction sends the blood to all parts of the system.

(*d*) Trace the anterior end of the heart forward and observe that it gradually becomes a firm-walled tube (**anterior aorta**) which lies along the side of a larger tube, *intestine*. The anterior aorta conveys aërated blood from the ventricle to the "foot," viscera and the anterior region of the body. At the posterior end of the ventricle observe a similar blood vessel (**posterior aorta**) which divides into right and left branches. This vessel supplies aërated blood to the posterior regions of the body. * Make a careful sketch of the pericardial cavity, showing the heart, aortas and intestine.

(*e*) Examine blood corpuscles, either fresh, which may be taken from the auricle by means of a pipette, or in a permanent preparation. Note the form and size and color of the corpuscles. Sketch.

H.—THE ALIMENTARY CANAL.

(*a*) Beginning at the mouth, determine the course and regions of the alimentary canal. Insert a seeker into

*The student should have an opportunity to see the pulsations of the heart in a live Mussel. For this demonstration the valve should be removed as described in the foregoing directions (p. 44) and the animal kept under water.

the mouth and pass it in a dorsal direction as far as it will easily go. Now with your scissors slit open this region of the alimentary canal, *œsophagus*, and note its position and length.

(*b*) Note the enlargement, *stomach*, at the inner end of the œsophagus. Carefully examine the shape and size of the stomach. Along its ventral wall, seek a small opening which leads obliquely down and backward into another portion of the alimentary canal, *intestine*. Use the seeker to guide you in the direction of the intestine. Now slit open this portion of the intestine. Make a sketch of the alimentary canal from the mouth to this point, and develop it as you proceed to reveal the direction and position of the remaining portions of the canal.

(*c*) Observe a lobed gland, *liver*, surrounding the stomach and a portion of the œsophagus. Represent the liver in your sketch.

(*d*) Carefully trace the intestine to its entrance into the anterior end of the pericardial cavity which begins just back of the stomach. Note whether the diameter of the tube or the thickness of its wall has varied.

(*e*) Trace the remaining portion of the alimentary canal (**rectum**) horizontally through the pericardial cavity, and observe that it seems to enter the anterior region of the ventricle. Carefully dissect away the ventricle, which really passes around the sides and over the rectum. Bring up your sketch to this point.

(*f*) Trace the rectum from the posterior end of the pericardial cavity, and observe that it passes along over the dorsal region of the posterior adductor muscle, and then obliquely downward, and opens through a small slit, *anus*, into the cloacal chamber.

(*g*) Examine a transverse section through the body of the Mussel in the region of the "foot" and identify all the structures which you have now learned. Make a careful sketch of this section.

(*h*) Examine (*lp*) preparations of the young stages, or larvæ (**glochidia**) of the Mussel. Sketch.

(*i*) Write a careful description of the anatomy of the Mussel from your notes and sketches, and make drawings of the alimentary canal and circulatory system.

OTHER WORK.

1. General view of the morphology and physiology of the Mussel.
2. The significance of the absence of appendages and the unsegmented body in the Mussel.
3. The life-history and habits of the Mussel.
4. The general characteristics of the Oyster, Snail, Squid, Cuttlefish and Nautilus with comparisons.
5. The characteristics of Bryozoa and the Ascidia.
6. Oyster culture and the economic interests in the Mollusca.
7. Characteristics and the classes of Mollusca.

COMPARATIVE REVIEW ON THE MORPHOLOGY OF THE INVERTEBRATE TYPES.

It is important at this point that the student should take a thorough review on the invertebrate types, and that this should embrace not only his laboratory work upon these types but also his lectures and collateral reading included under the head of *Other Work*.

1. Comparative review of the general external appearance and the habits of the invertebrate types of animals.
2. The hard parts or exoskeletons,— spicules, spines and

ossicles, setæ, chitinous shells and bristles, calcareous shells.

3. The organs of digestion and assimilation, forms of prehension, digestion in the simple cell, in the specialized cell, the enteron or primitive alimentary canal, the true alimentary canal, the more highly specialized alimentary canal, the glands aiding in the process of digestion.
4. The organs of respiration,— by means of general surface; specialized regions; tracheæ; gills.
5. The organs of circulation,— in the simple cell; in an aggregation of simple cells; true blood vessels, a heart and arteries; lacunæ and veins; true capillaries and a closed system; the simple "arterial heart."
6. The muscular system;— contractility as a characteristic property of protoplasm; specialized muscle processes; muscle fibres; muscles and a complex system.
7. The sense organs;— sensation in the animalcule; specialized nerve fibres; nerves and ganglia; specialized nerve centres; organs of sight; organs of hearing.
8. Reproduction;— simple cell division; budding; specialization of two kinds of cells in the same animal; gonads, distinct sexes. The course of development from the ovum.
9. A general view of the gradual advance from the simple to the complex in structure, and from the simple to the highly specialized in function.

References. — 31 — 43 — 44 — 79 — 80 — 88 — 89 — 91 — 106 — 115 — 116 — 120 — 122 — 124 — 126 — 129 — 140.

STUDY IX.

A STUDY OF A RIVER PERCH.

*PERCA FLAVESCENS.**

As an example of the simpler vertebrated type, having a true internal skeleton.

Material Required.—(1) Live minnows or any small fish in an aquarium; (2) a supply of fresh Perch†; (3) a dissection showing the digestive and circulatory systems; (4) a dissection of the central nervous system; (5) a mounted endo-skeleton of the Perch; (6) a supply of disarticulated bones; (7) microscopical preparations of tissues; (8) preparations showing the principal stages in the development of the egg.

Habitat.

The Common Perch inhabits the streams and lakes generally throughout the northern regions of the United States. It is an important food-fish, and may be obtained from the market during all seasons of the year. The River Perch spawns in the Spring, depositing its eggs in large tubular, zigzag masses. The young (**small fry**) hatch in from two to four weeks, the period varying with the temperature of the water

LABORATORY WORK.

EXTERNAL MORPHOLOGY.

A.—THE GENERAL FORM OF THE BODY.

(*a*) Note the outline of the body as seen from the lateral aspect. As seen from the dorsal aspect. Make sketches

*This guide will serve quite as well for the study of any Fresh-water Perch or Sea Perch, and will also answer fairly well for a Bass.

†During warm weather the fish should be kept on ice when not in use. For general study alcoholic specimens are not so desirable.

(*del. 2'*) representing these outlines. To what does its form seem to be adapted?

(*b*) If the body is narrower between the lateral aspects than between the dorsal and ventral, the fish is said to be *compressed;* if *vice versa*, it is said to be *flattened.* Which is true of the perch?

(*c*) Take the following measurements in centimetres: (1) *Length*, from tip of snout to base of tail fin; (2) *Depth*, the greatest distance between dorsal and ventral edges; (3) *Width*, the greatest thickness between lateral aspects; (4) *Length of head*, from tip of snout to posterior tip of the flap situated on the side of the head. What are the relative lengths of head and body?

(*d*) Note the general shape of the head. Observe the relation of the head to the body. Is there a neck?

B.—THE APPENDAGES.

(*a*) Observe the fan-like structures (**fins**) extending along the dorsal edge of the body. With your forceps stretch them open. Are they alike in shape and size?

(*b*) Observe the bony structures (**fin-rays**) which constitute the skeleton or frame work of the fin and determine its shape.

(*c*) Examine the anterior fin (**anterior dorsal**) and observe that its fin-rays are hard and stiff, and consist of only one piece (**spinous,** or **inarticulated rays**). How many spinous rays are there in the anterior dorsal fin? Do you find any other kind of ray?

(*d*) Examine the other dorsal fin (**posterior dorsal**) and observe the character of its fin-rays. Bend them with your fingers and examine (*m*) their structure, and note that these (**soft,** or **articulated rays**) are of a different

kind. How many soft rays do you find in the posterior dorsal? Are there any spinous rays?

(*e*) Compare the soft rays with the spinous rays and note at least three differences. The soft rays of some fishes are composed of an elastic substance (**cartilage**) which represents bone in an incomplete state of development. Are any of the rays in the Perch cartilaginous?

(*f*) Examine the membrane which constitutes a part of the fin. How is it related to the fin-rays with reference to position? Stretch open the dorsal fins and sketch them.

(*g*) Examine the fin at the posterior end of the body, *caudal fin*. Spread it out and note its general shape. Are its dorsal and ventral lobes symmetrical (**homocercal**) in every respect or does the back-bone seem to extend into the upper lobe and so render the external appearance of the tail unsymmetrical (**heterocercal**)?

(*h*) How many and what kind of fin-rays do you find in the caudal fin? Make an outline sketch of the caudal fin.

(*i*) Examine the fin (**anal fin**) on the ventral edge of the body just in front of the caudal fin. Note the number and kind of rays. Sketch.

(*j*) Note that all the fins which you have already examined are in the median line of the body (**median fins**) and extend in a vertical plane, that they occur singly and not in pairs, there being only one of each kind.

(*k*) Observe a pair of fins (**pectoral fins**) one on each side of the body, just back of the head. Examine to ascertain the number and kinds of rays in each. Sketch.

(*l*) Observe another pair of fins (**ventral fins**), situated farther back and more nearly on the ventral region of the body. Ascertain the number and kinds of fin-rays. Sketch one of the ventral fins.

(*m*) The pectoral fins in the fishes are supposed to be *homologous* to the wings of the bird, or the fore-legs of a higher animal. Are they also *analogous* to these appendages? Give your reason. Explain the *homology* and *analogy* of the ventral fins.

C.—THE EYES.

(*a*) Note and describe the exact location of the eyes. Identify and examine the eye sockets (**orbits**) and eye-ball.

(*b*) Observe the bony walls of the socket, and note the small bone (**ante-orbital**) in front, and one below (**sub-orbital**) forming this wall. Sketch (× 2) outline of a socket and these bones.

(*c*) With your forceps, touch the edge of the eye-ball at different points and observe its free motion (**range of vision**). Compare the range of vision in the Perch with that of higher animals and man.

(*d*) Observe the dark circular space (**pupil**) in the eye-ball. Note the colored membrane surrounding the pupil (**iris**). Describe its color in the Perch.

(*e*) What is the pupil of the eye? Its color and why? Sketch the eye-ball with iris and pupil.

(*f*) Observe the transparent outer coat, *cornea*, over the iris and pupil. Note its smooth surface.

(*g*) Can you find eye-lids or eye-lashes in the Perch? Demonstrate that the eye-ball may be slightly protruded and retracted. What means of protection of the eye has the Perch?

D.—THE NOSTRILS.

(*a*) Identify the nostrils (**nares**) and note their number, exact location and arrangement.

(*b*) Examine with the bristle to determine their internal relation. Are any connected? If so, which ones?

With bristle carefully determine whether the nostrils open through the roof of the mouth.

(*c*) Compare the nostrils in the Perch with those of man. What inference do you draw concerning the function of the nostrils in the Perch?

E.—THE MOUTH.

(*a*) Identify the jaws and note the method and extent of opening. Note the shape of the *mouth* when open and when closed.

(*b*) Observe the large openings (**gill-openings**) along the side of the head. Pass your forceps through the mouth and out at one of these openings and note its extent.

(*c*) Observe the bones in the upper lip (**pre-maxillaries**). Move them slightly with your fingers and determine their number and shape. Touch them with the tip of your little finger. Have they teeth? Sketch a pre-maxillary (× 2).

(*d*) Observe the bones just back of the pre-maxillaries (**maxillaries**), and note their number and shape. Have they teeth? Sketch a maxillary (× 2).

(*e*) Are there any bones in man which are similar in structure and position, *homologous*, to the pre-maxillaries in the Perch? Are there any which are similar in function, *analogous*? Name them.

(*f*) With the tip of your little finger feel in the roof of the mouth, and find a patch of fine teeth. Note the position of the bone (**vomer**) which bears these teeth.

(*g*) Note the bones (**palatines**) along the sides and a little way back of the vomer. Have they teeth?

(*h*) Study the shape of the lower jaw when the mouth is wide open. When it is closed. Of how many bones does it consist? Note the anterior bone

(**dentary**) of the lower jaw. Are these teeth on the dentary? Sketch (× 2).

(*i*) Examine the tongue. Note its shape. Can it be protruded beyond jaws?

F.—THE GILL-COVERS.

(*a*) Observe the large flap, or gill cover (**operculum**) along the side of the head. Note its shape and see which edges are free and which attached to the head. Note the large gill-opening between its posterior edge and the head.

(*b*) Observe the delicate bones of the operculum. Note the shape of the one extending farthest back (**opercle**) and ending in a spine. Note the shape of the one (**sub-opercle**) just below the opercle. And the one (**inter-opercle**) just in front of the sub-opercle. Note the bone (**pre-opercle**) in front of the opercle and observe its peculiarities.

(*c*) Note the patch of scales in the region (**cheek**) just in front of the pre-opercle. Now make a diagram of the entire operculum, showing the position and shape of the bones.

(*d*) Note a fan-like structure (**branchiostegal apparatus**) along the ventral edge of the operculum. With your forceps spread it open. What does it resemble? Of what is it composed? Where is it attached to the head?

(*e*) Note the skeleton (**branchiostegal rays**) of this apparatus. How do the rays vary in size?

(*f*) Note the membrane (**branchiostegal membrane**) which covers these rays. Now make a sketch of the branchiostegal apparatus.

(*g*) Observe the narrow-pointed region (**isthmus**) of the body between the branchiostegal apparatus of the two sides. Sketch

G.—THE GILLS.

(*a*) Raise the left operculum and observe the red structures, *gills*, beneath it. With your forceps lift the upper or *first* (**anterior**) gill. Where is it attached?

(*b*) Determine the central bony arch (**branchial**, or **gill-arch**) supporting the gill. Is it composed of several pieces or of a single piece?

(*c*) Examine (*m*) the red fringes (**gill-filaments**) along the edge of the gill-arch, and designate their exact position.

(*d*) Note the arrangement and exact position of the teeth-like structure (**gill-rakers**) along the arches. Note at least two additional facts about the gill-rakers.

(*e*) Depress the tongue with your finger and note the effect on the gill-rakers.

(*f*) Observe a red line, *blood-vessel*, along the base of the gill-filaments. What do you assume to be the function of the gill-arch? Of the gill-rakers? Of the filaments? Make a sketch of a complete gill ($\times$ 2).

(*g*) With your forceps lift the next, or *second* gill, then the next and so on. How many gills do you find? How many pairs has the Perch?

(*h*) Compare the gills on the same side and note the points of difference.

(*i*) Note the large space (**first gill-cleft**) between the operculum and the first gill. Where is the second gill-cleft? The third, etc.? How many gill-clefts are there? Compare their sizes.

(*j*) On the inner surface of the operculum in the dorsal region, note a red spot (**false-gill**).

(*k*) Remove a small tuft of gill-filaments and examine it under the microscope (*lp*). Sketch.

H.—THE SCALES.

(*a*) Observe the bony covering (**scales**), the *exoskeleton* of the body. Note their arrangement. Show by sketch.

(*b*) With your forceps pull out a scale from the ventral region of the body. Examine (*m*) it carefully and study the radiating and concentric markings, *striæ*, on its outer surface.

(*c*) Note that the scales (**ctenoid scales**) have one scalloped edge, and fine, straight comb-like teeth on the opposite edge. In some fishes the edges of the scales are smooth (**cycloid scales**).

(*d*) Note a distinct line (**lateral line**) extending along the sides of the body. Where are the ends of this line?

(*e*) Pull out and carefully examine a scale from the lateral line and note any peculiarity. Sketch. What is the true nature of the lateral line? Compare a lateral line scale with one from some other region.

(*f*) Examine (*m*) the delicate membrane, *epidermis*, which covers the scales. How is it related to the scales? Make a diagram representing a longitudinal sectional view of scales and membrane.

(*g*) Pull out a scale from a black spot and observe its color. Take one from a white or yellow spot and compare Where is the color, *pigment*, of the spots; in the membrane or in the scale?

(*h*) Make an outline drawing of a Perch, natural size, showing the left lateral aspect. Write a description of the external morphology from your notes and sketches.

THE INTERNAL ANATOMY.

I.—THE BODY-CAVITIES.

(*a*) Just in front of the anal fin, note an opening through the body wall, the external opening of the intestine,

anus. Hold the fish in the palm of your left hand with its ventral edge upward and anterior end pointing away from you. About half an inch in front of the anal opening thrust the point of one of the blades of your scissors through the body-wall and cut along the median line forward into the isthmus, being careful not to insert the blades so far as to injure the internal organs. Now lay the fish into the dissecting tray with its head pointing to your left and its ventral edge toward you. With your forceps lift the cut edge of the left body-wall, and beginning at the point of the first incision trim away as much of the body-wall as possible without injuring the organs. Lay this flap forward or remove it entirely.

(*b*) Note the form of the *body cavity* which is now laid open, Observe the silvery membrane (**peritoneum**) lining the body cavity.

(*c*) Trace the outline or boundary of the body cavity as seen from the ventral aspect. At its anterior limit, observe the membranous cross-partition (**false diaphragm**) which separates the larger, or abdominal body cavity from a smaller cavity, *pericardial cavity*, in front. Note the shape of the pericardial cavity and make a diagram showing the outline of the body cavities (× ½).

J.—THE DIGESTIVE ORGANS.

(*a*) Take a general view of the organs in the abdominal cavity. Move them slightly to ascertain their relation and connections. Identify as nearly as you can.

(*b*) Study the alimentary canal, beginning at its anterior end. Pass a probe back through the mouth into the straight *œsophagus* which leads into the abdominal

cavity, and locate the end of the probe back of the diaphragm. Now, without breaking or cutting any tissue, trace the alimentary canal from this point.

(*c*) Examine the large *stomach*. Turn the fish and examine it also on its right side. Note the shape of the stomach. Find the point where the stomach ends and the smaller portion of the alimentary canal (**small intestine**) begins. From which part of the stomach does the intestine arise? Make an outline sketch of the alimentary canal up to this point, disregarding for the present any organs attached to it or lying upon it.

(*d*) Now trace the small intestine along its course and loops to the point where it becomes larger and more nearly straight. Represent the small intestine in your last sketch.

(*e*) Trace the straight portion of the intestine (**large intestine**) to its external opening, *anus*, and complete your sketch of the alimentary canal.

(*f*) Observe the thin membrane, *mesentery*, which holds the intestine in place. In which region of the abdominal cavity is the mesentery attached?

(*g*) Study the large reddish organ, *liver*, lying in the anterior region of the abdominal cavity and chiefly on the left side of the median line. How many lobes has the liver? Where is it attached?

(*h*) On the posterior surface of the liver, observe a greenish thin-walled sac (**bile sac**, or **bile bladder**). Can you find any connection between the bile sac and the intestine? Prick the bile sac with your dissecting needle and see the greenish liquid, *bile*, flow out. What is the function of the liver? Of what use to the perch is the bile? Sketch the liver and bile sac.

(*i*) Study the pointed, worm-like tubes (**pyloric cæca**) im-

bedded in fat at the junction of the stomach and intestine. Carefully clear away the fat to expose the cæca. Snip off a cæcum and carefully examine (*m*) it. What is the nature of it? How many cæca are there? Where are they connected. Sketch.

(*j*) Observe a small, reddish-brown body (**spleen**) a little way back along the intestine and in the mesentery. Has it any connection with the intestine? Sketch.

K.—THE REPRODUCTIVE AND EXCRETORY ORGANS.

(*a*) In the posterior region of the abdominal cavity, are the *gonads* or reproductive organs. In the Perch, as in all higher animals, the sexes are separate, hence only ovaries or spermaries exist in the same individual.

(*b*) In the female Perch, the gonad (♀) is a single structure, varying much in size with the season.* During the spawning season it may occupy the larger portion of the abdominal cavity. Note its color. Examine the ova (*m*). Sketch a small patch of ova.

(*c*) Can you find a delicate membranous tube, *oviduct*, connected with the ovary? Where does it lead? Make an outline sketch of the ovary.

(*d*) In the male Perch, the gonads (♂) consist of a pair of whitish structures in the dorsal posterior region of the abdominal cavity. Trace a small tube (**sperm-duct**) from each to an external opening just back of the anus.

(*e*) Make a careful sketch of the gonad, *spermary* or *ovary*, as the case may be, including the tubes leading away from it.

(*f*) In the dorsal region of the body cavity observe a white membranous sac (**air-bladder**). Carefully examine its

*NOTE.—If the female is studied during the spawning season it will be necessary to examine and remove the ovary before the digestive organs can be studied.

form and determine whether there is a small tube (**pneumatic tube**) connecting the air-bladder with the anterior region of the stomach or the œsophagus. Make an outline sketch of the air-bladder.

(*g*) Above the air-bladder against the roof of the abdominal cavity, observe a pair of dark, slender bodies (**kidneys**). Note their form and position. Trace the left kidney back to a pinkish sac (**urinary bladder**) in the posterior end of the abdominal cavity. Can you find its external opening just back of the anal opening. Sketch the left kidney, including the urinary bladder.

L.—THE ORGANS OF CIRCULATION AND RESPIRATION.

(*a*) *Examine the reddish, tubular structure, the *heart*, extending through the middle of the pericardial cavity. Observe the angular portion, *ventricle*, located in the ventral and posterior region of the pericardial cavity. Turn it slightly to ascertain its connections.

(*b*) Observe the dark irregular portion, *auricle*, located in front of the ventricle and slightly more dorsal. Note its shape and connection with the ventricle.

(*c*) Observe the large blood-cavity (**venous sinus**) which extends back from the auricle and in front of the false-diaphragm. Note that the venous sinus extends across the pericardial cavity, *i. e.* has two lateral divisions which enter the auricle.

(*d*) Observe the large blood vessel (**hepatic vein**) which passes forward from the liver through the false diaphragm into the pericardial cavity and enters the venous sinus. Can you discover any other *veins* entering the venous sinus? Make a diagram of the venous sinus, showing its connections.

* Injected specimens should be used whenever it is possible. Students can be directed to inject their own specimens, two working together, or several students may inject specimens for the entire class.

(*e*) Observe the light-colored, conical structure (**arterial bulb**) in front of the ventricle. Note its continuation forward into a large blood vessel (**branchial aorta**). Trace the branchial aorta forward and note the branches (**branchial arteries**) which it gives off right and left to the gill. Make a careful sketch showing all the compartments of the heart and the branchial aorta and its branches. Ventral view (*del.* 4′).

(*f*) Select one of the gills on the left side and carefully trace its artery along the base of the gill-filaments. At the dorsal ends of the gill arches, observe that this branchial vessel constitutes a branch leading into a larger longitudinal blood vessel (**dorsal aörta**). The dorsal aörta receives aërated blood from all the gills and conveys it into all parts of the body, and extends back along the ventral side of the backbone to the base of the tail. Make a sketch showing the relation of the branchial artery to the gill arch and its continuation into the dorsal aörta.

M.—THE CENTRAL NERVOUS SYSTEM.

(*a*) Remove* the head from the body by cutting across the anterior point of the isthmus and through the backbone in the region of the gill openings. Carefully cut and scrape away all the muscles on the head.† Now with a sharp scalpel slice off the upper wall of the bony case (**skull or cranium**) inclosing the brain.

(*b*) Observe the white or grayish organ (**brain**) in the cranium. Note that it is composed of several lobes, How many of these lobes can you find? Do they occur in pairs or singly? Does the brain fill up the

* If preferred, the head may remain attached to the body.

† The study of the central nervous system can be carried on to better advantage with material which has been hardened in alcohol or chromic acid. The skull and portions of the back bone may be kept in alcohol several days before studying the brain and spinal cord.

entire cavity? What do you suppose is the function of the loose tissue (**cellular tissue**) surrounding the brain?

(*c*) Observe the large rod-like structure (**spinal cord**) extending back from the brain through the chain of bones (**spinal column**) which constitute the back bone. Carefully examine the spinal cord along its side, about an inch or more from the brain, to see whether you can find small nerves (**spinal nerves**) branching from the central, or spinal nerve cord.

(*e*) Observe the enlargement (**medulla oblongata**) of the anterior portion of the spinal cord and the large nerves passing from its sides.

(*f*) Note the small median, somewhat triangular, lobe of the brain (**cerebellum**) which extends back over a portion of the medulla oblongata. Make a careful sketch of the parts of the central nervous system which you have thus far examined, and develop it as you proceed in your further study of the brain.

(*g*) In front of the cerebellum observe a pair of larger rounded lobes (**optic lobes**) which constitute the broadest portion of the brain. Continue your sketch.

(*h*) In front of the optic lobes, observe a pair of smaller, oval bodies (**cerebral hemispheres**) which meet in the median line. Note that the cerebral hemispheres taper forward into a pair of much smaller lobes (**olfactory lobes**) and that these continue into a pair of small nerves (**olfactory nerves**) which extend forward to the nasal cavities. Complete your sketch.

(*i*) Below the olfactory and cerebral hemispheres, observe a pair of very large and conspicuous nerves (**optic nerves**) which arise from the ventral surface of the optic lobes. Trace one of these nerves forward to the eye, dissect-

ing away any tissue necessary. See whether you can show that the nerve which arises from the left lobe passes to the right eye and the one from the right lobe to the left eye. Sketch (× 2).

N.—THE ENDO-SKELETON OF THE PERCH.

(*a*) Examine a mounted specimen of the internal frame-work (**endoskeleton**) of the Perch.

(*b*) Study the form of the back bone (**vertebral column**). Examine a separate bone of the vertebral column (**vertebra**) and note its central part (**centrum**) and its spinous projections (**processes**). How many processes has this vertebra? Compare the dorsal (**neural spine**) with the lateral ones (**ribs**). About how many pairs of ribs has the Perch?

(*c*) Examine the anterior and posterior surfaces of a centrum and describe them. Sketch a vertebra as seen in an end view, also as seen from the left side (× 4).

(*d*) Study a vertebra taken from the posterior region of the vertebral column. How many spinous processes has it? Are there any ribs? Sketch two views (× 4).

(*e*) Identify the bones of the head which you formerly studied in their natural position.

(*f*) Write a description of the anatomy of the Perch, and make careful drawings of the digestive, circulatory, and nervous systems.

OTHER WORK.

1. The central nervous system in the Perch.
2. Development of the Perch from the ovum.
3. Circulation and respiration in Fishes.
4. The general characteristics of Amphioxus and the Lamprey.

5. The general characteristics of the Elasmobranch and Ganoid fishes.
6. A comparative view of the exoskeletons and the endoskeletons in Fishes.
7. The chief characteristics of vertebrates.
8. The economic and scientific interests in Fishes.
9. The characteristics and the orders of Pisces.

References. — 11 — 27 — 31 — 34 — 51 — 60 — 72 — 81 — 89 — 91 — 99 — 106 — 115 — 116 — 120 — 122 — 123 — 124 — 125 — 129 — 150 — 165.

STUDY X.

A STUDY OF A FROG

RANA PIPIENS.

As an example of the Amphibian type, and an animal possessing highly developed limbs.

Material Required.—(1) Live Frogs; (2) a supply of alcoholic material; (3) dissections of the injected circulatory system; (4) dissections of the digestive system; (5) dissections of the central nervous system; (6) dissections of the muscular system; (7) a mounted skeleton; (8) a set of microscopical preparations; (9) a series of stages showing the development of the tadpole.

Habitat.

In most localities throughout the United States several species of Frogs are common. Any species will answer equally well for this study. The Frog is amphibious in its modes of life, living in the water and breathing by means of gills during its early life, and later inhabiting the land and breathing by means of lungs. In the spring the adult Frogs take to the water in ponds and ditches, where they deposit and fertilize their eggs. During the summer and early fall they inhabit the land, keeping in moist places, and returning into the water only for food and refuge from enemies. In the late fall, on the approach of cold weather, they bury themselves in the mud in ditches or at the bottom of the water, where they remain inactive and without taking food (**hibernate**) until the following spring.

The young, known as "polliwigs," or *tadpoles*, are hatched in the water by the heat of the sun during the months of May and June, the exact time varying with the season and the lati-

tude of the different localities. The eggs, or *spawn*, which are gelatinous masses floating at the surface of the water, may be collected and hatched in laboratory aquaria. Frogs may be collected during the warm seasons of the year, but are perhaps most accessible in the fall just before they retire into winter quarters. They may be kept alive and in good condition during the winter months in a wooden box properly ventilated. They should be allowed to creep under a moist cloth, and the box should be kept in a cool, damp cellar.

LABORATORY WORK.

A.—* OBSERVATIONS UPON THE LIVING FROG.

(*a*) Observe a live Frog while at rest, note his sitting posture and the position of his hind legs.

(*b*) Cause the Frog to jump, and note the process. In what way is it specially adapted to jumping? Of what other animal is this also true? Can you cause the Frog to walk or crawl?

(*c*) Observe the Frog in the water, and note its method of swimming. How is it specially provided for this mode of locomotion? What have the Frog and Perch in common to facilitate their swimming?

(*d*) While the animal is at rest, observe its throat, nostrils, and the sides of its body. What vital or life process is indicated by these actions? Observe the slow alternate distension and depression of your own chest. What vital process does this represent? How does the Frog perform the process of respiration?

(*e*) Observe carefully the slight pulsations on the right and left of the posterior end of the backbone. What vital process do these movements indicate? Place two

* These observations may be made while the student is collecting, or they may be carried on in the laboratory.

finger tips upon the inner, thumb side of your wrist, and feel your pulse. What vital process do you observe?

(*f*) Observe the frog's eyes. Do you discover eye-lids? Gently touch the eye with the point of your forceps and note the result. How many eye-lids for each eye, and where are they located when not in use?

EXTERNAL MORPHOLOGY.

B.—GENERAL FORM AND REGIONS OF THE BODY.

(*a*) Observe the general shape and appearance of the Frog. Has the Frog any external constriction or boundary (**neck**) between the *head* and the body proper (**trunk**)? Has it a tail?

(*b*) Note the outline of the head and trunk from the dorsal view. Observe the prominences over the eyes and the angular projections in the hump of the back. Sketch the outline of the head and body from a dorsal view (× ½).

(*c*) *Observe the prevailing color of the dorsal and lateral regions of the Frog. Note the color markings. Of what color is the ventral surface of the body? Examine some of the pigment spots (*m*) and sketch.

C.—THE HEAD.

(*a*) Note the triangular shape of the head. Observe the form and extent of the *mouth*. Open it and note the shape of the *upper* and *lower* jaws. Are they provided with teeth (*m*)? If teeth are present, note their position and shape. Which bones have teeth?

(*b*) Examine the tongue. Can it be protruded beyond the jaws? Note its attachment. What is peculiar about

*The color and markings should be observed on the live Frog, if possible, and compared at different times.

the tongue of the Frog? What do you suppose is its special function? Compare it with that of the Perch.

(*c*) Examine the *eyes* and compare them with those of the Perch. Name the points of resemblance and difference between the eyes of the Frog and those of the Perch.

(*d*) A little way back and below the eye, observe a thin portion of the skin, *tympanum*, or ear-drum, stretched over a firm ring, which outlines the external ear. With your needle prick a hole into the tympanum. Pass a tipped bristle through this pore and observe the points at which it appears in the mouth and the evident course of the tube (**Eustachian tube**) through which it has passed.

(*e*) Identify the nostrils, *nares*, near the tip of the snout. How many do you find, and how are they arranged? Pass a tipped bristle through one and carefully determine whether it connects with the interior of the mouth. Name the points of resemblance and of difference between the nostrils of the Frog and those of the Perch.

(*f*) Open the mouth and in the back part of the floor observe a small longitudinal slit (**glottis**) leading into a tube (**bronchial tube**) which conveys air to and from the respiratory organs.

(*g*) Observe (*m*) a small, spherical, sac-like body (**brow spot**) in the median line just in front of the eyes. This has a connection with an internal structure (**pineal eye**) of peculiar interest.

D.—THE LIMBS.

(*a*) Note the position of the limbs. To which fins in the Perch are they homologous? Why?

(*b*) Examine the anterior pair of limbs. Note that each consists of a proximal segment or *arm* (**brachium**), a *fore-arm* (**ante-brachium**), a *hand* (**manus**), and *fingers* (**digits**).

(*c*) Note the number of digits in each hand and their relative sizes. Sketch the left anterior limb and name the parts.

(*d*) Examine the posterior limbs. Note the subdivision of each into segment or *thigh*, *femur*, the *leg* (**crus**), the *foot* (**pes**), and the *toes* (**digits**).

(*e*) Note the number of digits in each foot and their relative lengths. Which is the *first* toe, the inner or outer? Note the membrane (**web**) between the digits. Sketch the left posterior limb, indicating and naming all its parts.

(*f*) Compare the two pairs of limbs in the Frog, stating the points of resemblance and difference. What is the general function of the limbs? With what structure in the Perch are they analogous, and why?

(*g*) Write a description of the external morphology of the Frog, and make careful drawings.

**THE ENDOSKELETON.*

E.—THE AXIAL SKELETON.

(*a*) Study the general plan and arrangement of the connected bones in a prepared skeleton. Observe that one series of bones forms a main central chain (**axial skeleton**) and the other bones, consisting of the limb bones and the bones to which they are attached (**appendicular skeleton**) constitute another series.

(*b*) Examine the axial skeleton and note that it consists of two principal regions, (1) the bones of the head (**skull**) and (2) the chain of bones, *vertebral column*,

extending back from the skull and constituting the backbone.

(*c*) In the skull observe the bones forming the hollow brain case (**cranium**) and the other bones (**facial bones**).

(*d*) At the posterior end of the cranium, observe a large opening (**occipital foramen**) through which the spinal cord is continuous with the brain in the cranium. Locate some smaller openings (**foramina**) in the cranium through which nerves pass out from the brain.

(*e*) Observe the smooth, rounded processes (**occipital condyles**) at the posterior end of the cranium, below and outside of the occipital foramen. Observe that these condyles form the articulation with the first vertebra (**atlas**) of the vertebral column.

(*f*) Identify the *premaxillary*, *maxillary*, and *dentary*. Which of these are provided with teeth? What points of resemblance have these bones to the corresponding bones in the Perch? How many bones enter into the lower jaw, *mandible?*

(*g*) Identify the *nasal* and *vomer*. Locate the orbit of the eye and note the number of bones which together form its boundary.

(*h*) Examine the vertebral column. Observe that its posterior end terminates in one long, slender piece (**urostyle**). How many true vertebræ are there in front of the urostyle?

(*i*) Sketch the dorsal view of the axial skeleton.

(*j*) Examine in detail a disconnected vertebra, using any one between the fourth and eighth inclusive. Observe the *centrum* or body of the vertebra. Note its concave anterior face and the convex articular knob on its posterior face. Observe the large longitudinal foramen above the centrum. Note that the portion

of the vertebra above the foramen (**neural arch**) contains several processes. How many processes project horizontally forward? How many project horizontally backward or outward, and how many *median processes* project obliquely upward and backward?

(*k*) Take two vertebræ and hold them in their natural relation. Now note the relation of the vertebræ in the mounted skeleton. Compare a vertebra of the Frog with a corresponding one of the Perch and name the points of resemblance and difference.

(*l*) Sketch a lateral and an anterior view of a vertebra of the Frog.

F.—THE APPENDICULAR SKELETON.

(*a*) Observe that the bones of the anterior limbs are attached to an *incomplete girdle* of bones (**pectoral arch,** or **shoulder girdle**) around the axial skeleton.

(*b*) Note that on the ventral side of the body there is a complicated bony structure, situated below the position of the heart. This consists of (1) a median, longitudinal, rod-like portion (**sternum**) composed partly of bone and partly of *cartilage;* (2) an anterior pair of slender bones (**clavicles**) extending laterally; (3) a posterior pair of more flattened bones (**coracoids**) which also extend laterally and enter into the articulation at the shoulder joint.

(*c*) Observe the dorsal portion of the girdle and note the triangular, flattened bone (**scapula**) which also enters into the articulation at the shoulder. Sketch the bones of the shoulder girdle and sternum.

(*d*) Examine the skeleton of the fore limb, and identify the bones in their order, beginning with the most proximal one,—(1) the arm bone (**humerus**); (2) the consolidated bones of the fore-arm (**radio-ulnar**) corre-

sponding to two distinct bones in the arm of man; (3) the wrist bones (**carpi**) consisting of two rows of three each; (4) the hand bones (**meta-carpi**) consisting of five bones, and (5) the finger bones (**phalanges**) arranged in series. With which bones does the radio-ulnar articulate? The humerus?

(*e*) Place the skeleton of the hand, palm down, and the shorter digits forward or inward and note the number. Now look for a very small digit (**thumb**) normally under the skin.

(*f*) Examine the second, third, fourth, and fifth fingers. Which is the longest digit and how do the others rank? How many segments or phalanges has each digit? Sketch a fore limb and name the bones included.

(*g*) Observe the relation of the hind limbs to the axial skeleton. Note that they are attached to a set of bones (**pelvic arch** or **hip girdle**) which articulate directly with the vertebral column, and with the ninth vertebra (**sacrum**), form a *complete girdle.* Observe that the ventral portion (**pelvis**) of the hip girdle consists of several united bones and that these form the articulation with the leg. Sketch the hip girdle.

(*h*) Examine the skeleton of a hind limb and identify (1) the thigh-bone, *femur;* (2) the shin-bone (**tibio-fibula**); corresponding to the tibia and fibula in man; (3) the ankle bones (**tarsi**); (4) the bones of the foot (**meta-tarsi**); and (5) the bones of the toes (**phalanges**). With which bones does the tibio-fibula articulate? The femur?

(*i*) Note that the inside digit (**hallux**), corresponding to the first or great toe in man is the smallest in the Frog. How do the digits rank in length? How many segments or phalanges has each?

(*f*) Sketch a hind limb and name the different bones included.

G.—THE BODY-WALL AND MUSCLES.

(*a*) Pin the animal down ventral side up and the head pointing to your left. With your forceps lift the skin in the posterior region of the abdomen (**pelvic region**) and with scissors cut forward along the median line to the tip of the lower jaw, being careful not to cut into the body-wall. Observe the very loose attachment of the skin to the muscular body-wall.

(*b*) From the beginning of this incision, cut transversely through the skin just in front of the left thigh. Make a similar transverse incision just back of the left arm. Now draw this flap of skin away and pin it down, and as you do this note the chambers (**lymph cavities**) between the skin and the muscles of the body-wall.

(*c*) Observe the muscle bands in the body-wall of the trunk. Note the median longitudinal band of muscles (**rectus abdominis**) in the form of a slender arrow-head. In which direction is the apex? At the anterior end of the rectus abdominis, observe on each side a wing-like band (**pectoralis major**) extending obliquely forward to the anterior limb. What is the function of the pectoralis major? Sketch these muscles.

(*d*) Observe a vein (**anterior abdominalis**) extending longitudinally along the median line through the rectus abdominis. Note also on the inner surface of the flap of skin a prominent vein (**great cutaneous**) running forward.

(*e*) Remove the skin entirely from the left hind limb as far distally as the foot, and study the form and arrangement of the muscles. Separate some of these mus-

cles by carefully tearing the *connective tissue* which binds them together, but leaving them attached at each end.

(*f*) Note the thickest region (**belly**) of one of the dissected muscles; also the end (**origin**) attached to the part less movable and the opposite end (**insertion**) attached to the more movable part of the leg. Observe the dense glistening substance (**tendon**) at the ends of the muscle.

(*g*) Can you determine the special function of any of these muscles? Sketch one or two muscles of the leg.

(*h*) With your forceps lift the body-wall in the pelvis and with scissors cut along the median line to the lower jaw, being careful not to injure the organs lying beneath. In the region of the anterior limbs it will be necessary to cut through a thin bone, *the sternum*. Also cut the wall right and left transversely in the pelvic region and pin back the flaps and anterior limbs to the fullest extent.

H.—DIGESTIVE ORGANS.

(*a*) Note the general arrangement of the internal organs. Pass the blow-pipe through the mouth into the *œsophagus*, and inflate the *stomach*. Note its position and shape.

(*b*) Trace the course of the alimentary canal and identify the *œsophagus*, *stomach*, and *intestine*. Sketch the œsophagus and stomach.

(*c*) Note the convoluted portion of the intestine, being the *small intestine*, and the short, straight portion, the *large intestine*. Note the color, shape, and position of each. Note the enlargement of the intestine (**cloaca**) near the *anus*. Represent these portions of the alimentary canal in your last sketch.

(*d*) Identify the *liver*, a large, brown, two-lobed mass. Note its position. Which is the larger lobe? Which lobe is subdivided? Identify the *bile-sac* and its *duct*, between the lobes of the liver. Sketch these organs.

(*e*) Identify the *spleen*, a small red structure which is located in the mesentery in the median line just in front of the large intestine. Has it any connection with the intestine?

(*f*) Observe a V-shaped, pale yellowish mass (**pancreas**), located in the mesentery along the first bend of the intestine. Can you find any connection between the pancreas and the alimentary canal? Add a sketch of the pancreas and spleen to your sketch of the intestine.

I.—THE REPRODUCTIVE AND EXCRETORY SYSTEMS.

(*a*) In the female Frog, identify the gonads or *ovaries*, which are dark masses situated in the abdominal cavity to the right and left of the median line. In the breeding season these organs may be relatively large and much lobed. Identify and trace the *oviducts*, which are long coiled tubes leading from the anterior part of the body cavity to the cloaca.

(*b*) Observe a pair of red, elongated, flattened bodies, *kidneys*, situated along the back bone, just in front of the cloaca. See whether you can determine their ducts (**ureters**) leading into the cloaca. Sketch the ovaries and kidneys with their ducts.

(*c*) In the male Frog, identify the gonads or spermaries, which are a pair of yellowish bodies much smaller than the ovaries, situated in front of or upon the anterior end of the kidneys. Try to identify the minute tubes leading into the kidneys.

(*d*) Observe the large bi-lobed sac (**urocyst**) situated just in front of the cloaca. If the urocyst is not easily observed, it may be inflated by the use of the blow-pipe. Sketch the gonads, kidneys, and urocyst.

J.—THE RESPIRATORY ORGANS.

(*a*) Observe the transparent oval sacs (**lungs**) situated along the sides of the œsophagus, and probably covered in part by the liver.

(*b*) Open the mouth of the animal wide and examine the glottis. Note the lateral folds of membrane and the chamber (**larynx**) below them.

(*c*) Insert the blow-pipe into the larynx and inflate the lungs. Observe that they are not very spongy, but more like hollow sacs. Note the short tubes (**bronchi**) which connect the lungs with the larynx. Sketch the respiratory organs.

(*d*) What organs in the Perch are analogous to the lungs in the Frog? Why?

K.—THE ORGANS OF CIRCULATION.

(*a*) Note the position of the *heart* and that it is enclosed in a thin-walled transparent sac (**pericardium**). Cut the pericardial sac away, taking care not to injure the heart or blood vessels.

(*b*) Observe the thick-walled conical apex (**ventricle**) of the heart, and the darker thin-walled base (**atrium**). Note the large vessel (**arterial trunk**) passing obliquely over the atrium from the ventricle and separating into two branches, one right and one left, at the base of the heart.

(*c*) Turn the apex of the heart forward and on its dorsal side note a dark-colored triangular sac (**sinus venosus**).

Observe two thin-walled veins (**pre caval veins**) which enter it from right and left. Note the branches forming each of these large veins. From what regions of the body do they bring blood?

(*d*) Observe another large vein (**post caval vein**) entering the sinus venosus at its posterior angle. Trace this vein back from the heart and determine from what regions and organs of the body it brings blood. How does the blood from the hind limbs and the pelvis get to the post caval vein? Sketch the heart and its connecting veins.

(*e*) Examine the branches which unite to form the arterial trunk, and note that each subdivides into three divisions for its own side of the body. Note that (1) the most anterior of the three (**carotid arch**) passes to the side of the pharynx and forward; (2) the middle one (**systemic arch**) passes around the œsophagus and back to unite with its fellow from the other side, and thence to the viscera and posterior regions of the body and fore limbs, and (3) the posterior arch (**pulmo-cutaneous arch**) which sends branches to the lungs and the skin. Trace these arteries and sketch.

(*f*) Carefully examine the interior of the atrium and determine a longitudinal membranous partition which divides the atrium into two chambers (a *right* and a *left auricle*).

(*g*) Make a diagram of the heart (*del. 2′*), showing the cavities and openings of vessels.

THE NERVOUS SYSTEM.

L.—THE CENTRAL NERVOUS AXIS.

(*a*) Take an alcoholic specimen and pin it under water, dorsal surface upward. Make a longitudinal incision

in the skin along the entire median line, loosen the skin and pin it back. Remove the muscles from the dorsal surface of the head and a short distance back of it.

(*b*) Now insert a point of your scissors into the occipital foramen, and carefully cut around the outer edge of the roof of the cranium, and remove the bony lid to expose the *brain*. In a similar manner expose the *spinal cord* for a short distance back of the head. The nervous axis now in view (**cerebro-spinal axis**) constitutes the principal portions of the nervous system.

(*c*) Observe that the brain and spinal axis are closely invested by a thin membrane (**pia mater**) and that the bony case containing them is closely lined by a tougher, pigmented membrane (**dura mater**). *Note the whitish liquid (**lymph**) which occupies the space between the pia mater and dura mater. Of what use do you suppose the lymph is?

M.—THE BRAIN.

(*a*) Study the dorsal view of the brain. Observe the pair of white elongated bodies, *cerebral hemispheres*, situated between the eyes, and note that they are separated longitudinally by a deep groove (**fissure**).

(*b*) Observe that the anterior extremities of the cerebral hemispheres merge directly into a pair of rounded bodies, *olfactory lobes*. Trace the olfactory lobes forward and note that they are continuous, with bands of nerves, *olfactory nerves*, which terminate in the nasal regions.

(*c*) Back of the cerebral hemispheres observe a pair of oval diverging bodies, *optic lobes*. Note the small median

* This observation is not very satisfactory on alcoholic specimen.

body (**pineal body**) between the posterior ends of the cerebral hemispheres.

(*d*) Back of the optic lobes note an enlargement, *medulla oblongata,* of the anterior end of the spinal cord.

(*e*) Make a careful sketch of the brain, representing and naming all the regions which you have now identified.

N.—THE CRANIAL NERVES.

(*a*) You can now study the nerves which are given off directly from the brain (**cranial nerves**). Cut through the *first* pair of cranial nerves, *olfactory nerves*, leaving as much of their stumps on the brain as possible, and carefully lift the anterior end of the brain and turn it slightly back to ascertain the origin of the *second* pair of cranial nerves (**optic nerves**). Cut these nerves, leaving long stumps as before.

(*b*) Note that the optic nerves diverge from an X-shaped prominence (**optic chiasma**), in which they really cross, the one from the left side of the brain passing to the right eye, and the one from the right side to the left eye.

(*c*) Carefully turn back the brain a little further and discover the *third* pair of cranial nerves (**motor oculi**). Note that they are smaller than the optic nerves, and take their origin in a spherical body (**pituitary body**) situated in the median line. The motor oculi supply certain muscles which move the eyes.

(*d*) Now carefully trace along the outer side of the medulla oblongata to identify the *fourth* pair of cranial nerves (**trochlear**) which supply a pair of muscles of the eye. Cut these as you did the former.

(*e*) A little way back of the trochlear note a pair of larger nerves (**trigeminal nerves**), which are really a union of

three cranial nerves,—the *fifth* (**trigeminal**) supplying the lining of the mouth and the muscles of the lower jaws; the *seventh* (**facial**) supplying the skin and muscles of the throat; and the *eighth* (**auditory**), which is the special nerve of hearing.

(*f*) Observe a pair of small nerves (**abducens**) which arise from the median ventral surface of the medulla oblongata, being the *sixth* pair of cranial nerves. These also supply certain muscles of the eyes.

(*g*) In about the same region, but from the sides of the medulla, note a pair of larger nerves, which really include the *ninth* (**glossopharyngeal**) and *tenth* (**pneumogastric**) nerves, the former supplying the tongue and muscles of the pharynx, and the latter the regions of the shoulder girdle and the lungs, heart, etc.

(*h*) Now turn back the brain so as to get a good ventral view and make a careful sketch, representing and naming all the regions of the brain and the cranial nerves. Now return the brain to its natural position.

O.—SPINAL CORD AND SPINAL NERVES.

(*a*) Examine the dorsal surface of the spinal cord in its natural position as far back as exposed to view. Note its form and size. Sketch it.

(*b*) Now take up the Frog, turn the animal on its back and pin it down, and remove the viscera, if this has not already been done. Remove all loose tissue, so as to leave the inner surface of the body-wall bare along the sides of the vertebral column. The entire series of nerves, *spinal nerves*, arising from the spinal cord is now exposed.

(*c*) Note the *first* spinal nerve (**hypoglossal**), which arises from the cord between the first and second vertebræ.

(*d*) Observe the *second* spinal nerve (**brachial**), a very large pair, leaving the vertebral canal between the second and third vertebræ. Trace the brachial nerve a little distance and note that it forms a union (**brachial plexus**) with the *third* spinal nerve. This nerve supplies the muscles of the shoulder and front limbs.

(*e*) Identify the *fourth*, *fifth*, and *sixth* spinal nerves.

(*f*) Identify the *seventh*, *eighth*, *ninth*, and *tenth*. Trace these nerves, and observe that they form a plexus (**sciatic plexus**) and then continue as one large nerve (**sciatic nerve**). The sciatic nerve is the largest in the body, and supplies the muscles of the hind limbs.

(*g*) Make a diagram to represent the arrangement of the spinal nerves, and their relation to the spinal cord (*del. 2′*).

(*h*) Write a description of the gross anatomy of the Frog and make careful drawings.

MINUTE ANATOMY.

P.—THE BLOOD AND BLOOD-VESSELS.

(*a*) Examine a microscopic preparation of blood (*hp*) and note the minute discs (**red corpuscles**). What is their shape and *color? Note the shape and appearance of the nucleus. Sketch several red corpuscles.

(*b*) Can you find (*hp*) another kind of bodies (**white corpuscles**) of various shapes and sizes? Sketch.

(*c*) Examine a preparation of lymph (*hp*) and note the form and * color of the corpuscles (**lymph corpuscles**). Which kind of blood corpuscles do these most resemble? Sketch.

(*d*) Study (*lp*) a microscopic preparation of a portion of the lung. Observe the larger vessels, *arteries* and *veins*,

*If the blood or lymph is studied from permanent preparations the natural color of the corpuscles has, of course, been changed.

and note their modes of branching. Can you distinguish between the arteries and veins? Trace a larger vessel into the minute net-work of blood vessels (**capillaries**). Note the black *pigment cells* of various form and size. Sketch a favorable portion of your preparation.

(*e*) Examine more carefully (*hp*) the capillaries and note their connections and mode of branching. Can you find blood corpuscles in the capillaries? Sketch a portion of the preparation as seen under the high power (*del.* 1½′).

Q.—TISSUES OF THE ORGANS OF DIGESTION.

(*a*) Study a microscopic preparation containing a transverse section of the *stomach*, *œsophagus*, and *small intestine*. Examine (*m*) the section of the stomach. Note the folds of tissue extending into the interior. Sketch the section (× 3).

(*b*) Examine (*m*) the section of the œsophagus and note the size as compared with that of the stomach. Study the different tissues (*lp*), of which the wall is composed. How many layers are there? Note (1) the outer layer, *peritoneum*, which encloses the others; (2) next to the peritoneum observe a double *muscular layer*, the outer portion of which has its fibres arranged longitudinally and the inner circularly; (3) next a layer (**sub-mucosa**) of connective tissue through which blood-vessels and minute absorbent vessels (**lymphatics**) pass. The lymphatics convey a colorless fluid (**lymph**) and generally closely accompany the blood-vessels; next (4) note the inner layer (**mucous membrane**) which constitutes the inner lining of the œsophagus. Sketch a portion of the section representing tissues of all the layers and in their relative thickness.

(*c*) Study (*lp*) the section of the small intestine. Note the minute projections (**villi**) on the mucous lining. Identify the four layers of tissue which you examined in the section of the œsophagus. Note (*hp*) the minute branches (**lacteals**) of the lymphatics in the villi, and their close relation with the capillaries. Sketch a villus, representing lacteals and capillaries.

(*d*) Study a microscopic preparation of the liver (*lp*), cut perpendicular to the surface. Note that the substance of the liver is subdivided into numerous masses (**lobules**). What is the form or outline of the lobules? Note the tissue (**interlobular connective tissue**) which connects the boundaries of the lobules. Sketch several adjacent lobules.

(*e*) Note (*hp*) blood-vessels (**interlobular veins**) in the connective tissue. Carefully study the structure of the lobules and note nucleated masses (**liver cells**). Observe their outline and the form and appearance of the nucleus. Sketch several adjacent liver cells.

R.—THE MINUTE STRUCTURE OF THE KIDNEYS.

(*a*) Examine (*lp*) a microscopic preparation of a kidney, cut longitudinally and parallel with the flat surface. Note the twisted tubules (**urinary tubules**) extending in all directions, and hence cut, some transversely, some obliquely, and others longitudinally. Sketch.

(*b*) Observe the clear circular spaces (**malpighian capsules**) scattered through the tissue. Note the granular mass (**glomerules**) which are likely to be shown in some of the capsules. Sketch a capsule containing the glomerules.

(*c*) Examine the section (*hp*) more carefully and note the appearance of the above structures. Sketch small portions.

S.—NERVOUS TISSUE.

(*a*) Examine a permanent preparation of a transverse section of the spinal cord and determine (*m* and *lp*) its general form. Note the deep, wide groove (**ventral fissure**) and a similar but narrower one on the opposite side (**dorsal fissure**). Note a small opening (**central canal**) situated near the middle of the section and in a line with the ventral and dorsal fissures. Is there a *right* and a *left half* of the spinal cord? Can you identify the two halves. How?

(*b*) Observe that the nervous tissue appears in general as two kinds, the darker tissue (**grey matter**) and the lighter tissue (**white matter**). Note the general plan and outline of the regions of grey matter. Where is it located with reference to the white matter? Are the lateral halves of the cord symmetrical?

(*c*) Note a pair of posterior ends (**dorsal horns**) of the grey matter, one in each half of the cord, and a similar pair (**ventral horns**) in the ventral region. Note also the central region which connects the lateral *halves* of grey matter (**grey commissure**).

(*d*) Make a careful drawing of the spinal cord, representing the white and grey matter.

(*e*) Examine more carefully (*hp*) the tissue (**histological element**) of which the cord is composed. Note the cells of the grey matter. Do you find cells containing several processes (**multipolar nerve cells**) and a distinct nucleus? Can you find some with only two processes (**bipolar cells**) or only one process (**unipolar cells**)? Of which kind do you find most? Carefully draw one or more of each kind.

(*f*) Examine the cells of the white matter. How many kinds do you find? Note the few branched cells

(**neuroglia cells**) which constitute the principal element of the connective tissue (**neuroglia**) of the spinal cord. Sketch one or more neuroglia cells.

(*g*) Note the circular structures (**nerve fibres**) in the white matter. In most regions of your section these fibres are cut transversely. Are the nerve fibres all of the same diameter? Note the central core (**axis-cylinder**) of the nerve fibre. Sketch.

(*h*) At the base of the anterior fissure nerve fibres pass from one half of the cord across to the other; here these fibres may be seen in longitudinal view. Examine the longitudinal fibres and sketch.

(*i*) Write a description of the minute anatomy of the Frog and make careful drawings.

OTHER WORK.

1. A review of the endoskeleton of the Frog, and comparisons with that of the Perch.
2. The life history of the Frog.
3. The special characteristics of Salamanders and Newts.
4. A comparison of the different forms of adult Amphibia with the typical stages in the development of the Frog. Animal ontogeny and phylogeny.
5. The gradual transition from aquatic to terrestrial habits in the Amphibia.
6. A comparison of the general morphology of Amphibia with that of fishes.
7. The relation and interdependence of the organs in a higher animal.
8. The characteristics and the orders of Amphibia.

References. — 13 — 20 — 31 — 34 — 43 — 44 — 60 — 62 — 72 — 78 — 79 — 81 — 104 — 105 — 107 — 109 — 112 — 116 — 120 — 122 — 124 — 125 — 126 — 129 — 133 — 150 — 165.

STUDY XI.

A STUDY OF A TURTLE.

*CHRYSEMYS MARGINATA.**

As an example of the reptilian type.

Material Required.—(1) Some live Turtles; (2) a set of small, alcoholic specimens, *in toto*, for external study; (3) a set of articulated bones of the axial endoskeleton and exoskeleton; (4) sets of bones of the appendicular skeleton; (5) wet preparations of the injected vascular system; (6) dry preparations of the respiratory organs; (7) wet preparations of the digestive and urino-genital organs.

Habitat.

The Turtle inhabits the sandy and muddy shores along streams, lakes, ponds, and adjacent swamps and meadows. It is an inoffensive, timid animal, avoiding man whenever possible. Its food consists of fish, frogs, crayfish, and aquatic insects and vegetation. The Turtle, like most of our reptiles, is *oviparous*, burying its large white eggs in the sand or earth to be hatched by the heat of the sun. The Turtle is an animal of very slow growth. Turtles may be kept alive in the laboratory indefinitely, provided the proper food is supplied. If the water in the aquarium is deep, provision should be made to enable the animals to come to rest above the surface of the water.

LABORATORY WORK.

A.—†OBSERVATIONS ON THE LIVING TURTLE.

(*a*) Observe the Turtle out of water and note its method of locomotion. Does it walk, crawl, or jump? Note the order in which its two pairs of limbs move.

* Any species of Chrysemys will answer equally well.

† See note on p. 70.

(*b*) Hold a stick to its mouth and note the result. Observe the form of its jaws. Are they provided with teeth?

(*c*) Touch the eye and observe the number of eyelids. Note the inner one (**nictitating membrane**). Where is each attached?

(*d*) Cause the head and appendages to retract into the shell. Now turn the Turtle on its back and observe its method of getting right side up again.

(*e*) Observe the Turtle in water and note its method of swimming.

(*f*) How long does it remain under water? Do you see bubbles of air passing to the surface while its head is in the water? Why cannot the turtle remain under water indefinitely?

B.—THE EXOSKELETON.

(*a*) Observe the general shape of the shell. Note that it consists of an upper portion (**carapace**) and a lower or ventral portion (**plastron**). Note the connection (**bridge**) between the carapace and plastron.

(*b*) Examine the carapace and note that it is marked off into sections (**bony epidermal plates**). Study the shape and arrangement of the bony plates.

(*c*) Note (1) the smaller plates arranged around the edge (**marginal plates**); (2) the row along the dorsal median line (**dorsal plates**); (3) those between the marginal and dorsal rows (**costal plates**). How many plates of each kind and how many plates in the carapace?

(*d*) Make an outline sketch of the carapace (*del. 2'*), and in correct proportion, representing accurately all the bony plates.

(*e*) Examine the plastron and note its general shape and the arrangement of its plates. Do you find a median

row as you did in the carapace? How many longitudinal rows are there?

(*f*) Observe the plates of the plastron by pairs and note their size and shape, (1) the triangular anterior pair (**gular plates**); (2) the larger pair just back of the gular plates (**postgular plates**); (3) the pair in the region of the pectoral girdle (**pectoral plates**); (4) the next (**abdominal plates**); (5) the next (**preanal plates**); (6) and the smaller triangular pair (**anal plates**). Make a diagram of the plastron, (*del. 2'*), representing and naming the plates.

(*g*) Note also the two irregularly shaped plates on each side which form the bridge or connection between the plastron and carapace. Note the anterior pair (**axilar plates**), carved out to accommodate the fore limbs, and the posterior pair (**inguinal plates**) in front of the hind limbs. With which plates of the plastron proper do these join?

(*h*) Observe the exoskeleton (**bony scales**) on the head and appendages, and note their relation to the leathery skin.

(*i*) Examine the hand and foot and note the number of digits in each. Note the horny structures (**claws**) on the digits.

(*j*) Write a description of the external morphology of the Turtle and make careful drawings.

INTERNAL ANATOMY.

C.—THE AXIAL ENDOSKELETON.

(*a*) Study the axial endoskeleton in a dry preparation of connected bones, examining the preparation from the ventral side. Note the modifications of the vertebræ in different regions of the vertebral column.

(*b*) Note the form and number of vertebræ in the neck (**cervical vertebræ**) situated between the head and the shoulder girdle. Sketch the ventral view of a cervical vertebra.

(*c*) Note the form and number of vertebræ in the series (**dorsal vertebræ**) between the last cervical and the first one immediately back of the pelvic arch.

(*d*) Observe the flat bones (**ribs** or **costal plates**) extending from the vertebral column laterally toward the edge of the carapace and united with it. How many pairs of ribs can you identify? Observe their exact form and the order of arrangement.

(*e*) Sketch two adjacent dorsal vertebræ and the ribs connecting with them on one side (*del. 2'*).

(*f*) Examine the vertebræ back of the pelvic arch (**caudal vertebræ**). Note their varying size and shape and state their number. Sketch the fourth and eighth caudal vertebræ.

D.—THE APPENDICULAR ENDOSKELETON.

(*a*) Study the bones which constitute the *pectoral arch*, and note that on each side three bones unite to form the articulation at the shoulder.

(*b*) Identify (1) the *scapula*, being the dorsal one, (2) *coracoid*, being the posterior ventral one, and (3) the *precoracoid*, being the anterior ventral bone. Which articulate with the humerus?

(*c*) Identify the *humerus*, *radius*, *ulna*, *carpi*, and *phalanges*. How many of each kind?

(*d*) Sketch one of the anterior limbs including its bones of the shoulder girdle.

(*e*) Study the bones which constitute the *pelvic arch*. Note of how many bones on each side, it consists.

(*f*) Identify (1) the large bone (**pubis**) projecting in an anterior and ventral direction, (2) the peg-like bone (**ischium**) back of the pubis, and (3) the bone (**ilium**) extending obliquely upward and backward. Which of these bones articulate with the femur and which with the vertebral column?

(*g*) Identify the *femur*, *tibia*, *fibula*, *tarsi*, *metatarsi*, and *phalanges*. How many of each kind?

(*h*) Sketch one of the posterior limbs, including its bones of the pelvic arch.

E.—THE RESPIRATORY ORGANS.

(*a*) Identify the *trachea*, *bronchi*, and *lungs*.

(*b*) Pass a string around the œsophagus, inflate the lungs by inserting the blow-pipe through the mouth of the Turtle, and tie the string to retain the air in the lungs. Arrange the lungs in their natural position and sketch the respiratory organs.

(*c*) Note the rings of cartilage in the trachea. What is their function?

F.—THE DIGESTIVE ORGANS.

(*a*) In a wet dissected preparation identify the *œsophagus* or gullet. Examine it and compare its wall with that of the trachea. Why the difference?

(*b*) Identify the *stomach*, *small intestine*, *large intestine*, *cloaca*, *anus*.

(*c*) Identify the *liver*, *bile bladder*, *pancreas*, and *spleen*.

(*d*) Arrange the digestive organs in a convenient order and make a careful sketch of the entire system.

G.—THE URINO-GENITAL SYSTEM.

(*a*) Identify the *kidney*, *urinary bladder*, and sketch.

(*b*) Identify the gonads, being either (♀) *ovary*, including *ova* and *oviducts;* or (♂) *spermary*, including *spermatozoa* and *sperm-ducts*. Sketch.

H.—THE CIRCULATORY SYSTEM.

(*a*) Note the position and general form of the *heart.* Observe the *pericardial sac* and the *pericardium.*

(*b*) Compare the heart of the Turtle with that of the Frog with reference to size and shape. Do you find external evidence of two auricles, a *right auricle* and a *left auricle?*

(*c*) Observe the great arteries originating from the ventricle and passing forward over the ventral surface of the auricles. Examine these vessels carefully and determine how many there are at the very beginning.

(*d*) Now observe the one most ventral of these arterial trunks (**pulmonary artery**) which takes its origin from the anterior edge of the ventricle and a little to the right of the median line. Trace the pulmonary artery forward and note its right and left branches leading respectively to the right and left lungs.

(*e*) A short distance in front of the heart observe the remaining arterial trunks, and note that apparently there are three distinct arteries, one passing forward in the median line, and the other two curving upward and back, one to the right and the other to the left.

(*f*) Examine carefully this latter pair of arteries, and see whether you can determine that the one passing to the left side of the body (**left aorta**) really has its origin on the *right* of the median line in the ventricle, and also that the one passing to the right side of the body (**right aorta**) has its origin on the *left* of the median line of the ventricle. Trace the right and

left aortæ around their curves and a short distance back through the body cavity, and note that they unite and form a single artery (**dorsal aorta**) which passes posteriorly along the vertebral column.

(*g*) Carefully examine the left aorta near the junction with its fellow, and note that two relatively large branches are given off. Trace the first (**cœliac artery**) and determine to what organs it distributes branches. Trace the second (**mesenteric artery**) and determine its distribution.

(*h*) Trace the dorsal aorta back and learn what you can about its distribution.

(*i*) Examine the right aorta at the point of its origin, and note that the artery which passes forward along the median line (**innominate artery**) is really a branch of the right aorta. Trace the innominate artery forward, and note that it divides into two branches, one passing to the right and the other to the left.

(*j*) Trace the left branch of the innominate, and observe that it forms two branches, one passing outward (**subclavian artery**) and the other (**carotid artery**) passing forward. Trace each of these far enough to determine their distribution.

(*k*) Now make a careful sketch of the heart and arterial system as far as you have studied it, and name its parts.

(*l*) Lift the heart forward and examine the veins entering the auricles. Note the short trunk (**pulmonary vein**) entering the left auricle. From what organ does this vessel bring blood and what kind?

(*m*) Now examine the entrance of veins into the right auricle. Note that there are three veins entering at the same point, through the *venus sinus*, two (**precaval**

veins) coming from an anterior direction and one (**postcaval vein**) from the posterior direction.

(*n*) Learn what you can of the source of the caval veins, and make a sketch of the heart and the venous trunks.

(*o*) Write a description of the anatomy of the Turtle and make careful drawings.

OTHER WORK.

1. General review of structure of the exoskeleton in the Turtle, and comparisons with that of the Snake and Lizard.
2. Morphology of the organs of respiration and circulation in the Turtle.
3. A comparative view of the anatomy of the Turtle, Snake and Lizard.
4. The significance of hibernation in certain groups of Vertebrates.
5. The significance of "cold-blooded" and "warm-blooded" Vertebrates.
6. The characteristics and the orders of Reptilia.

References. — 31 — 60 — 81 — 91 — 114 — 116 — 120 — 122 — 124 — 125 — 129 — 150 — 165.

STUDY XII.

A STUDY OF A PIGEON.

**ECTOPISTES MIGRATORIUS.*

As an example of the Aves, or the bird type of animals.

Material Required.—(1) Some live Pigeons; (2) one or more mounted specimens of the wild Pigeon; (3) one or more mounted skeletons of the Pigeon; (4) a supply of disarticulated bones; (5) a supply of the different classes of feathers; (6) one or more dry Pigeon skins, including the head, limbs and feathers; (7) a preparation of the injected blood vessels; (8) a dissection of the digestive and urino-genital systems; (9) a dissection of the central nervous system.

Habitat.

The Wild Pigeons and Doves are common to most sections of the United States. They live in pairs or in flocks, and are usually migratory, feeding almost exclusively on seeds and grains. The female lays two eggs in a rudely-constructed nest, and is assisted by the male bird in hatching and caring for the young. The young are nourished by a creamy fluid, secreted in the crop of both sexes of the adult during the breeding season. The Rock-Pigeon is the ancestral form of all the numerous races of domestic and fancy Pigeons.

LABORATORY WORK.

THE ENDO-SKELETON.

A.—GENERAL OBSERVATIONS.

(*a*) Examine a mounted skeleton of the Pigeon and note its general plan and form. Note the points of support which balance the body while the animal is standing. Where is the greater weight of the body, anterior or

* NOTE.—The common domestic Dove will serve quite as well as the Wild Pigeon for this study.

posterior of these supports? Why does the bird not topple forward? Note the points of support when the bird is flying.

(*b*) Note the curvature of the vertebral column. Make a diagram, consisting of a pair of lines, to represent the curves of the vertebral column, as seen from the left side. Add to this diagram the outline of the head and body. Now add a diagram of the left wing and leg (*del.* 3′).

B.—*THE AXIAL SKELETON.

(*a*) Note the general outline of the head, lateral and dorsal views. Note the rounded *cranial* portion, the tapering *facial* portion in front of the latter, and the large *orbits*.

(*b*) Examine the *lower jaw*, or *mandible*. Is it directly articulated with the skull? Note the three-knobbed bone (**quadrate**) which articulates with the jaws and the skull.

(*c*) Note the bone, *dentary*, which forms the anterior end of the mandible. How does the dentary in the Pigeon differ from those in the Perch, Frog, and Turtle?

(*d*) Examine the *upper jaw* and note the bone (**pre-maxilla**) which forms the anterior end of the beak. Note the slender rod-like bone (**maxilla**) extending back from the pre-maxilla.

(*e*) Note that the pre-maxilla contains two proximal projections, one above and the other below the nasal cavity. These posterior projections articulate with the anterior ends of a bone (**nasal**) which connects the pre-maxilla with the skull.

*NOTE.—The student should have access to a mounted skeleton in studying the position and relation of the bones. He should also be provided with a supply of disarticulated bones for study in detail and sketching.

(*f*) Note the bone (**frontal**) which forms the upper boundary of the orbits, and the dorsal surface of the cranium. Note the bones (**parietals**) just back of the frontal and, if possible, trace their articulation with the frontal.

(*g*) At the posterior end of the skull, note the nearly circular aperture, *foramen magnum*, through which the spinal cord enters the cranium.

(*h*) Note the rounded knob, *occipital condyle*, just in front of the foramen magnum. How does it differ from that of the Turtle?

(*i*) Observe a cup-like depression (**tympanic cavity**) at the lateral and hinder end of the skull. Note the prominent lip on the bones which outline this cavity. Just within this lip is attached the *tympanic membrane*.

(*j*) Note in the middle of the tympanic cavity an upper aperture (**fenestra ovalis**) and a lower one (**fenestra rotunda**). In life, the fenestra ovalis lodges a slender bone (**columella**), the outer end of which is attached to the tympanic membrane, and conveys the vibrations of the latter to the auditory nerve.

(*k*) Note the bony frame-work (**hyoid apparatus**) situated just below the mandibles and extending in the same direction. This apparatus is situated in the floor of the mouth and supports the tongue, and represents, in part, the branchial arches of the Perch.

(*l*) Make a sketch of the lateral view of the skull and name the bones which you have studied.

(*m*) Examine the vertebral column and note the different regions. Note the first vertebra that bears a pair of ribs which are united ventrally with the sternum. This is the first *thoracic vertebra*, and all in front of this may be regarded as *cervical vertebræ*. How many cervical

vertebræ are there? Note their variation in size and form. How many have ribs? Sketch the dorsal and lateral views of a cervical vertebra belonging to about the middle region of the neck.

(*n*) Note the *thoracic vertebræ*. Observe that they have free ribs and that they are closely united by their centra and the processes of their arches. These vertebræ are all included in the thoracic series, and all, excepting the last, bear free ribs. How many thoracic vertebræ are there?

(*o*) Note the form of the *ribs* (**vertebral ribs**) borne on the thoracic vertebræ. Observe that they are united with a *ventral* series of ribs (**sternal ribs**) borne on the sternum. How many pairs of sternal ribs are there? Sketch the posterior view of a disarticulated thoracic vertebra, including its ribs.

(*p*) Back of the thoracic region, and including the last thoracic vertebra, note a region of the vertebral column, "*sacrum*," in which the vertebræ are intimately fused. The first two or three are the *lumbar* vertebræ. These are the most indistinct, and bear very short transverse processes. The next three or four are the *sacral*, and bear somewhat longer processes. The following five are *caudal* vertebræ, but are fused and enter into the formation of the "sacrum."

(*q*) Observe the *free* caudal vertebræ back of the "sacrum," and note the number and their dorsal and lateral processes. At the posterior end of the vertebral column, note the irregularly shaped bone (**plowshare bone**) which represents several fused vertebræ.

(*r*) Examine the *sternum*, and note its upper concave surface and its broad ventral, vertical plate (**keel**). What do you suppose is the function of the keel? Give a

reason for your supposition. Make two sketches, a left lateral, and a dorsal view.

C.—THE APPENDICULAR SKELETON.

(*a*) Study the *shoulder girdle.* Identify the *scapula* and the *coracoid,* and note their form and relation. Note the cavity (**glenoid cavity**) for the articulation of the humerus. Sketch the scapula and coracoid of one side, representing them in their proper relations.

(*b*) Identify the *clavicle.* Note that the clavicles unite in the middle to form one bone (**furcula**), known as the "wish-bone" or "merry-thought."

(*c*) Describe *the articulation* of a coracoid, that is to say, name the bones with which the coracoid articulates at its anterior end, and state the kind of articulation, and then do the same for its posterior end.

(*d*) Observe the plan of the *anterior limb* or wing. Identify the *humerus.* Note that the *antebrachium* consists of two distinct bones, the *ulna* and *radius,* the former being somewhat larger than the latter. What marked differences are there between the antebrachium of the Pigeon and that of the Turtle?

(*e*) Describe the articulation of the humerus. Sketch either the humerus or ulna. Name the one which you have sketched, and designate its proximal and distal ends.

(*f*) Examine the very much modified *hand,* and note that there are only two small bones, the *carpi,* to represent the wrist; one (**radiale**) on the radial or thumb side, and the other (**ulnare**) on the ulnar or inner side of thehand.

(*g*) Note that only three metacarpals are present, the *first* is small; the *second* is long and stout; and the *third* is long and slender. All are fused together at their proximal ends.

(*h*) Note that the first and third digits are completed with single *phalanges*, while the second is provided with two, the proximal one being large and much flattened.

(*i*) Make a sketch of the wing and name all the bones.

(*j*) Study the *hip girdle*, consisting of the large bones which extend along the side of the "sacrum" and are fused with it. Note the round floorless cup (**acetabulum**) in in the lateral region of the girdle. This is the articular cavity for the femur.

(*k*) Note that the *hip girdle* consists of two large bones, one on each side of "sacrum," and separate from each other. Each bone (**os innominatum**) is composed of three fused bones, the boundaries of which are not always easily found.

(*l*) Note that the largest bone (**ilium**) extends along the "sacrum" and above the acetabulum. Another (**ischium**) extends back of the acetabulum in the form of a vertical blade, and the third (**pubis**) is a slender rod which extends from the acetabulum back along the ventral edge of the ischium.

(*m*) Note that all the bones of the innominatum enter into the formation of the acetabulum. Sketch the lateral view of the os innominatum, and name the bones included.

(*n*) Examine the *femur* and note its articulating processes. Note the *crus*. How many bones do you find? Observe the larger bone (**tibio-tarsus**) and the small one (**fibula**) at the proximal end of the former. Are they free or fused? Which joint of the leg represents the knee? Do you find any trace of the patella? Which joint represents the heel?

(*o*) Note the third large bone (**tarso-metatarsus**), which is formed by the union of the tarsi and metatarsi, there being no separate tarsi in the adult.

(*p*) Study the foot and note the number of digits present. The digit pointing backward represents the *first*, *hallux*, or great toe, while the *fifth digit* is not present. State the number of phalanges for each digit. Make a sketch of the leg and name all the bones.

(*q*) Write a description of the endoskeleton of the Pigeon, and make careful drawings of the principal bones which you have sketched in your notes.

EXTERNAL MORPHOLOGY

D.—GENERAL EXTERNAL CHARACTERISTICS.

(*a*) Observe the general form of the Pigeon. How does the relative size of the head, neck and limbs compare with those of the Turtle and Frog?

(*b*) Note the form of the *head* and its pointed beak. Note that the beak is composed of an upper and a lower part (**upper** and **lower mandibles**). Compare the mandibles and note how they are related.

(*c*) Observe the *tongue*, note its peculiarity, and compare it with that of the Frog. What difference in function is there?

(*d*) Note the position and form of the nostrils. Determine whether they have internal openings. Compare with those of the Perch and Frog.

(*e*) Just back of the nostrils, note a naked swollen patch of skin (**cere**), situated at the base of the upper mandible. What is the significance of this characteristic?

(*f*) Note the position, shape, and color of the eye. How many eye-lids do you find? Is a *nictitating membrane* present? If so, locate it. Make a diagram ($\times 2$) of the eye, representing all the parts which may be seen externally.

(*g*) Carefully brush the feathers forward to find the external opening of the ear (**external auditory aperture**). Describe its location. Can you identify a *tympanum* and a *tympanic cavity?* Compare the external ear of the Pigeon with that of the Frog. What peculiarity of the feathers which cover the external ear (**auriculars**) do you note?

(*h*) Observe the flexible *neck* and compare it with that of the Turtle and Frog.

(*i*) Make an outline sketch of the left lateral view of the head, representing the external characters which you have studied.

E.—THE EXO-SKELETON,—FEATHERS AND HORNY SCALES.

(*a*) Examine the feathery covering of the Pigeon. Why should the feathers be regarded as an exo-skeleton?

(*b*) Are the feathers found on all regions of the body? Where do you find spaces (**apteria**) which are bare? What regions (**pterylæ**) are covered with feathers?

(*c*) How many kinds of feathers do you find? Note the largest and strongest (**quill-feathers**). Where are they located, and what do you suppose is their function? Note the number of tail-quills.

(*d*) Examine the wing-quills. Observe those borne on the hand (**primaries**) and note their number. Note the number borne on the forearm (**secondaries**). Do you find quills (**tertiaries**) on the arm? Make a simple diagram (*del. 2'*) representing the skeleton of the wing and indicate the position of the wing-quills.

(*e*) Note that the quill-feathers are overlapped by smaller feathers (**wing-coverts**). Do you find these on both the upper and lower surfaces of the wing? What do you suppose is their function?

(*f*) Note the smaller feathers (**contour-feathers**) which cover nearly all parts of the body. What is their formation?

(*g*) Observe the minute rudimentary feathers (**filoplumes**) which occur abundantly over the body.

(*h*) Examine the parts of a quill-feather. Observe the central portion (**stem**) and note its proximal hollow portion (**quill**) and its distal solid portion (**shaft**).

(*i*) Observe the small opening (**inferior umbilicus**) at the proximal end of the quill and another (**superior umbilicus**) at its distal end.

(*j*) Note the expanded portion of the feather (**vane**), extending along each side of the shaft. Observe that the vane is composed of narrow branches (**barbs**) attached to the shaft. Sketch a quill-feather (*del.* 3′).

(*k*) Remove a barb and examine it (*m* and *lp*). Note the rows of small barbs (**distal barbules**) attached along its distal edge, and a similar row (**proximal barbules**) along its proximal edge. What differences do you observe between the *proximal* and *distal* barbules (*lp*).

(*l*) Examine (*hp*) two barbs in their natural relation and describe the relation of the adjacent proximal and distal barbules. Sketch.

(*m*) Examine the covering of a *tarsus* and of the *toes*. Note the horny shield-like scales (**scutella**) which protect the tarsus in front. Note the shape and the relation of the scutella. Sketch a few adjacent scutella. On account of this covering the tarsi of the Pigeon are called *scutellate*.

(*n*) Now observe the form and arrangement of the scales (**reticulum**) on the posterior surface of a tarsus. Sketch. This surface is called *reticulated*, on account of the shape and arrangement of its scales.

(*o*) Note the horny scales on the toes. Is there a definite arrangement of these scales? Note the sharp, horny claws of the foot. Compare the horny covering and

claws of the foot of the Pigeon with that of the Turtle.

OTHER WORK.

1. Demonstration of the general anatomy of the Pigeon.
2. The principal types of Birds, and their distinguishing characteristics.
3. The affinity between Birds and Reptiles.
4. The development of the bird from the egg.
5. The significance of the high temperature of the blood in Birds.
6. The migration, habits, and distribution of Birds.
7. Variation and its cause. Example from Pigeons.
8. The theory of Natural Selection and the leading facts upon which it is based.
9. The characteristics and the orders of Aves.

References. — 31 — 34 — 43 — 60 — 81 — 83 — 84 — 91 — 93 — 98 — 99 — 104 — 105 — 106 — 108 — 112 — 115 — 116 — 120 — 121 — 122 — 124 — 125 — 128 — 129 — 130 — 131 — 138 — 148 — 150 — 160 — 162 — 163 — 164 — 165 — 168.

STUDY XIII.

A STUDY OF A CAT.*

FELIS DOMESTICATA.

As an example of the higher vertebrate or mammalian type.

Material Required.—(1) A live Cat; (2) a mounted skeleton of a Cat; (3) specimens of skulls of other mammals; (4) a collection of disarticulated bones of the Cat and other mammals; (5) a dissected preparation of the digestive system of a small Cat†; (6) a preparation of the injected arteries and veins of a kitten; (7) a preparation of the central nervous system; (8) a set of microscopical preparations of the skin, showing the development of hairs.

Habitat.

The Wild Cat (*Felis catus*) is the "Common Cat" of zoölogy, but is now found native in only comparatively few countries. The common domestic Cat (*Felis domesticata*) is found in every civilized community, and is represented by many varieties, all of which are probably descendants of the domestic Cat of Egypt, whose ancestors were probably the native Cat (*Felis maniculata*) of northern Africa.

LABORATORY WORK.

A.—OBSERVATIONS ON THE LIVING CAT.‡

(*a*) Note the general form of the body and the different regions of the animal, *viz.*, *head*, *neck*, *trunk*, *tail*, and *legs*.

(*b*) Note the covering of hair, or exoskeleton, its color and texture. In what regions of the body are no hairs present?

* In this Study the Rabbit or Dog may be substituted for the Cat.

† Kittens of about five weeks of age, on account of their smaller size, are more desirable than adult specimens, for demonstration preparations, and are also more convenient to preserve in alcohol.

‡ The pupil may make these observations and notes at his home, and the instructor, if he prefers, may subsequently review the points before the class, with the aid of a live Cat.

(*c*) Compare the exoskeleton of the Cat with those of the Pigeon, Turtle, and Perch, with reference to form and structure.

(*d*) Note the large, strong hairs, or whiskers (**vibrissæ**) situated on the upper lips. What do you suppose to be their function? Make a sketch ($\times \frac{1}{2}$) of the end of the nose and lips (**muzzle**), in front view, representing the whiskers.

(*e*) In what other regions are long hairs also present? Has the Cat eyelashes or eyebrows?

(*f*) Examine the eyes carefully and note their size, shape, and color. What is the shape of the pupil? Is its greater diameter in a vertical or horizontal direction? What advantage or disadvantage do you see in this characteristic? Sketch an eye.

(*g*) Let the Cat look into a dark closet, or hold her eyes shut for about a minute, and then suddenly allow a bright light to shine into her eyes, and quickly observe the change in the pupil. Describe what took place and try to explain how and why.

(*h*) Examine the eyelids. Can you find the third eyelid? If so, where is it located and how does it compare with that of the Pigeon?

(*i*) Examine the external ears carefully and note their position and shape. Are they movable? What is the function of the external ear? Sketch one.

(*j*) Observe the limbs and note their position and shape. Are they similar as to structure and function? Compare the limbs of the Cat with those of other four-legged animals (**quadrupeds**) already studied.

(*k*) Compare the limbs of the Cat with those of a two-legged animal (**biped**) already studied. Which pairs of limbs are homologous? Why?

(*l*) Examine the *paws* of the Cat. Note their shape and the number of digits in each. Are they all alike? Sketch the ventral view of a paw.

(*m*) Observe the claws carefully and note that they are capable of being withdrawn (**retractile**) from sight and touch. What advantage can you see in retractile claws? Compare the claws of the Cat with those of the Dog.

(*n*) Write a description of the external appearance of the Cat.

B.—THE GENERAL FRAME-WORK OF THE CAT.

(*a*) Study the general plan of the mounted skeleton of the Cat. What is the direction of the vertebral column or main axis of the trunk? Compare it with the direction of the main axis in the trunk of the human skeleton.

(*b*) Which of the typical animals of former studies have horizontal axes? Do any possess a vertical axis?

(*c*) Make a diagram (*del. 2'*) to represent the general plan of the skeleton.

(*d*) Observe the shape and relative size of the vertebræ in different regions of the vertebral column of the mounted skeleton. Note the number of *cervical*, *dorsal*, *lumbar*, and *caudal vertebræ*, respectively. Compare with the human skeleton.*

(*e*) From a collection of disarticulated bones of the Cat, select vertebræ to represent each of the principal regions of the backbone. Sketch the anterior face of a *cervical*, *dorsal*, and *lumbar vertebræ*, avoiding the first and second cervical.

(*f*) Observe and note the peculiarities in the form and articulation of the most anterior vertebra, *atlas*, and the

* See note on p. 111.

second (**axis**) in the skeleton of the Cat. Note the pointed projection (**odontoid peg**) extending forward from the axis. How is it related to the atlas ?

(*g*) Identify the atlas and axis among the disarticulated bones and note the number of processes for occipital condyles. Sketch an anterior and lateral view of the atlas and axis.

(*h*) Observe and identify the different bones in one of the anterior limbs in the skeleton of the Cat, and compare them with the corresponding bones in the arm of the human skeleton, as to position, number and shape.

(*i*) Observe and identify the different bones in one of the posterior extremities, and compare with the leg of the human skeleton.

C.—OBSERVATIONS ON THE SKULL AND TEETH.

(*a*) Observe the general shape of the skull of the Cat. How does it differ from the human * skull ?

(*b*) Identify and compare in the two skulls, the *superior maxillaries*, *inferior maxillaries*, *molars*, *frontals*, *parietals*, *occipitals*, *etc.*

(*c*) Sketch the outline (*del 2'*) of a lateral view of the skull of the Cat, carefully locating the external opening of the ear. Make a similar sketch of the human skull, reduced to the same size, being careful to retain the correct proportions.

(*d*) Now in your sketch of the skull of the Cat, with the aid of a rule, draw a sharp line from the anterior tip of the upper jaw through the opening of the ear, and another from the former point through the upper and most anterior point of the frontal bone. The angle formed by these lines is called the *facial angle*,

* If a human skeleton is not available, a manakin or chart may be substituted.

and is an important measurement in the comparative study of skulls.

(*e*) Draw similar lines on your sketch of the human skull. Estimate or measure the *facial angle* of each in degrees and compare.

(*f*) Examine the teeth in the jaws of the Cat. Note the size and shape of the front teeth (**incisors**). How many incisors are there altogether? How many on the right and how many on the left side of each jaw?

(*g*) Indicate the arrangement and number of incisors in the upper and lower jaws in the form of a double fraction, thus, *i.* $\frac{a\ b}{c\ d}$ in which *a*, *b*, *c*, *d* represent the number of incisors in the right and left upper, and right and left lower jaws respectively.

(*h*) Back of the incisors note the large, sharp-pointed teeth (**canines**). Write the formula for the canines, using the letter *c.* as the abbreviation.

(*i*) Observe the irregular-shaped teeth back of the canine (**premolars**), including all, excepting the last one in each row. Write the formula.

(*j*) Describe the remaining teeth (**molars**), and write the formula.

(*k*) Now write all the preceding formulæ in a line to represent the complete dentition (**dental formula**) for the Cat.

(*l*) What do you suppose is the special function of each kind of teeth in the Cat? State your reason.

(*m*) Make a careful drawing of one of each type of teeth found in mammals. Write a description of the skull and teeth of the Cat.

OTHER WORK.

1. The general anatomy of the Cat, and the principal characteristics of Mammals.

2. The circulatory system in Birds and Mammals. The structural elements of blood. The shape of blood corpuscles in different groups of Vertebrates.
3. Dental formulæ in Mammals. Development of teeth. Temporary and permanent sets in Man.
4. Morphology of the mammalian eye and ear.
5. Development and histology of bone. Classes of bones as to form of development.
6. Morphology of the nervous system in Mammals.
7. Reproduction in Mammals.
8. The characteristics and orders of Mammalia.

References.—31—43—60—77—81—91—98—105—106—110—112—116—122—124—125—129—150—165.

COMPARATIVE REVIEW OF THE VERTEBRATE TYPES.

The pupil should now make a comparative review of the morphology of Vertebrates, including his laboratory work, lectures, and collateral reading.

1. Comparative view of the endoskeleton in Vertebrates.
2. Comparative view of the organs of locomotion, and the homology in the limbs in different groups of Vertebrates.
3. Dermal structures or exoskeleton,—scales, bony and horny plates, quills, feathers, hairs, claws and nails.
4. Comparative morphology of the organs of digestion and the variation with food and habits in different groups of Vertebrates.
5. Comparative morphology of the organs of circulation,—simple heart of two chambers; a heart of three chambers; the double heart of four distinct chambers: solitary aortic arch.
6. Comparative morphology of the organs of respiration,—gills, air-sacs; lungs; complete diagram.
7. The phylogeny of the Vertebrate ear.

8. Comparative morphology of the nervous system and relative degree of intelligence in different groups of Vertebrates.

9. Affinity of the groups in the animal kingdom.

10. Artificial and natural systems of classification in natural history.

General References. — 3 — 25 — 27 — 37 — 42 — 43 — 48 — 49 — 51 — 59 — 61 — 62 — 75 — 81 — 83 — 84 — 86 — 93 — 108 — 111 — 120 — 139 — 143 — 160 — 162 — 163 — 164.

PART II.

PLANT TYPES.

NOTE.

Technical terms occurring in the Animal Studies, should they also occur in the Plant Studies, do not, as a rule, again appear in full-face type with definitions.

STUDY I.

A STUDY OF GREEN SLIME AND THE YEAST PLANT.

PROTOCOCCUS VIRIDIS AND SACCHAROMYCES CEREVISIÆ.

As examples of the simplest forms of unicellular plants; a cholorophyll-bearing plant and a saprophyte. To represent the Protophytes, or sexless plants.

Material Required.—(1) Protococcus in a fresh condition; (2) brewer's yeast.*

Habitat.

Protococcus is a minute, green, unicellular plant, growing on damp stones, flower pots and the trunks of trees, where it has the appearance of a dark green slimy coating. It may be collected with the bark from the trunks of trees at all times of the year. The protoplasm of the cell is enclosed by a relatively thick cell-wall which protects it against desiccation. Protococcus is found in all parts of the United States.

The Yeast Plant or sprouting fungus is a unicellular plant which can grow only in sugary or saccharine fluids. There are several species of these sprouting fungi, and all are capable of exciting alcoholic fermentation. The most easily obtained species is the brewer's yeast (*Saccharomyces cerevisiæ*).

LABORATORY WORK.

A.—THE MORPHOLOGY OF PROTOCOCCUS.

(*a*) Note the general appearance of Protococcus, growing on a piece of bark from a tree. Observe how it has spread over the surface of the bark (*m*).

* Compressed or dried yeast may be used instead of the brewer's yeast.

(*b*) With your scalpel scrape off a little, mount in water, and examine it (*lp*). Note the general appearance of the cells.

(*c*) Note the relation of the cells; are they solitary or connected in clusters or colonies (**one-cell, two-cell stages,** etc.)?

(*d*) Are the cells all of the same size? Sketch one of the largest (*del.* ½′), and one of the smallest of the solitary cells to show their shape and relative size.

(*e*) Find as many kinds of colonies or cell-stages (*lp*) as possible, and sketch a colony of each kind. Do you find a green coloring matter (**chlorophyll**) in the cells?

B.—MINUTE STRUCTURE AND THE EFFECT OF REAGENTS.

(*a*) Apply a drop of alcohol* and watch the effect (*lp*), and note the result.

(*b*) Examine your preparation more in detail (*hp*) and determine whether there is a nucleus and cell-wall present. Where is the chlorophyll found? Do you find chlorophyll in the cell wall? In the nucleus? Sketch a typical cell and represent all its structures.

(*c*) Apply a drop of iodine* and note the effect (**reaction**) on the different structures of the cell, viz., the cell-wall (**cellulose**); the *nucleus* and *protoplasm*. Do you find starch present?

C.—MORPHOLOGY OF THE YEAST PLANT.

(*a*) Observe some brewer's yeast. Is it a thick liquid (**semi-liquid**), or a thin liquid? Note its color.

(*b*) Do you find a deposit on the sides and bottom of the vessel containing the liquid? This sediment consists of the minute Yeast Plant.

(*c*) Place a drop of the Yeast on a clean slide and lay on

* The instructor should give careful directions on using reagents on the slide.

the cover-glass and examine it (*hp*). Note the shape of the cells (**torulæ**).

(*d*) Are the torulæ all of the same size and shape? Sketch one of the largest and one of the smallest. How do they compare with the cells of Protococcus in size and shape?

(*e*) Are any of the cells connected into clusters or colonies (**sprout-chains**)? Note how the cells or torulæ of the sprout-chain are arranged. Compare their arrangement with that of the Protococcus cells. Sketch one or two sprout-chains (*hp*).

D.—MINUTE STRUCTURE AND THE EFFECT OF REAGENTS.

(*a*) Examine the torulæ more carefully (*hp*) and decide whether there is a *cell-wall*, *nucleus* and *vacuoles*. Sketch a large torula and indicate its minute structures.

(*b*) Do you find any chlorophyll in the Yeast Plant? A plant which contains chlorophyll has the power of preparing its own food, which is sugar or starch, directly from the elementary substances,—that is to say, from the water, earth and air; but plants which have no chlorophyll are dependent for their food upon other plants or animals.

(*c*) Apply a drop of magenta and note the reaction. What is the effect on the cell-wall? Protoplasm? Nucleus? Vacuoles?

(*d*) Apply on a new preparation a drop of iodine and note the results. Do you find starch present?

(*e*) Compare Protococcus and the Yeast Plant as to their mode of cell multiplication, *reproduction*. Protococcus multiplies by *fission*, the Yeast Plant by *budding*. In which animals did you find these methods of reproduction?

(*f*) Examine the torulæ which about six or eight days ago

were sown on a fresh-cut surface of a potato and kept under a bell-jar. Do you find torulæ (*hp*) containing small internal cells (**ascospores**)? Note number and arrangement of the spores. This represents another method of reproduction in the Yeast Plant.

(*g*) Write a careful description of Protococcus and the Yeast Plant, at the close of which enumerate all the points of similarity and points of difference in the two plants.

OTHER WORK.

1. The nature of a unicellular plant and its essential elements.
2. The effect of temperature and food supply on the growth of the Yeast Plant.
3. The formation of carbon dioxide gas.
4. The function of chlorophyll, starch, cellulose and sugar.
5. The foods of plants.
6. The nature and characteristics of a true or typical plant; of a saprophyte; of a parasite.
7. Morphology and physiology of Bacteria.
8. A synopsis of the characteristics of Protophyta and a list of the classes.

References. — 5 — 12 — 18 — 19 — 20 — 26 — 27 — 38 — 43 — 44 — 62 — 66 — 71 — 79 — 92 — 96 — 108 — 126 — 134 — 147 — 152 — 158 — 169.

STUDY II.

A STUDY OF A BROOK-SILK.

SPIROGYRA QUININA.

As an example of a simple multicellular plant, which although composed of many cells is yet physiologically unicellular. To represent the Zygophytes, or unisexual plants.

Material required.—(1) Fresh Spirogyra in the vegetative condition; (2) fruiting Spirogyra, fresh or preserved in equal parts of 90% alcohol and glycerine. *Reagents:* (1) iodine; (2) glycerine; (3) alcohol.

Habitat.

Brook-silk, or Pond-scum, is a filamentous alga, belonging to the genus Spirogyra, and is found almost everywhere abundant in fresh-water ponds and slowly-flowing brooks. It forms masses of long, unbranched, bright-green, silky threads which float at the surface or in the water. It is quite slippery to the touch. Spirogyra may be found in its vegetating condition at any time during the warmer seasons of the year, and in this condition is of a bright green color. Its fruiting occurs mainly from early spring to the latter part of July. In its fruiting condition the threads form crinkled and tangled masses of a yellowish color. Various species may be found intermixed and growing in the same mass. Spirogyra may be kept in the vegetative condition throughout the year in aquaria jars in the laboratory, by supplying the proper food solution.* Any of the larger species will serve for this study.

* For Sach's Food-solution for green plants see formula in List of Reagents.

LABORATORY WORK.

A.—GENERAL CHARACTERS AND GROSS MORPHOLOGY OF SPIROGYRA IN ITS VEGETATIVE CONDITION.

(*a*) Observe a mass of Pond-silk in the aquarium jar, and note its general appearance and color.

(*b*) Examine (*m*) a few threads (**filaments**) in water in a white dish. With your dissecting needles separate the filaments in order to determine their length. About how long are they? Are all of the same length and diameter? Do you find any threads with branches?

(*c*) Place a few filaments in a phial, add some alcohol and after six or eight minutes note the result. What does this result indicate?

(*d*) Mount a filament in water and examine (*lp*) it. Of what is it composed? How are the cells arranged? Are they uniform in size? Sketch a portion of the filament showing several adjacent cells.

(*e*) By careful focusing, examine the internal structures of the cell. Note the special bands (**chlorophyll bands** or **chromatophores**). In which direction of the cell do the chromatophores extend? How many do you find in one cell?

(*f*) Trace a filament to the end,* and note any difference between the size and form of the end cells and those in other parts of the thread. Sketch the terminal cells.

B.—MINUTE ANATOMY OF THE VEGETATIVE FILAMENT.

(*a*) Examine a favorable cell (*hp*) and determine its exact shape. How many times does the chlorophyll band pass around the cell? Sketch a cell with its chlorophyll bands (*del* 1½).

* The filament may happen to be broken, hence you may not reach the natural end or terminal cells.

(*b*) Examine by careful focusing one of the chlorophyll bands and note the small bodies (**nodules**) which occur at intervals. Apply iodine.

(*c*) Now observe the nodule again and note the central light structure (**pyrenoid**) and the deep colored bodies* (**starch grains**) surrounding it. What evidence have you that the latter are starch grains? Sketch a chromatophore representing nodules, pyrenoid, and starch grains.

(*d*) Identify the *nucleus* and note its position and shape. Can you find a nucleolus. Sketch.

(*e*) Take a fresh thread and mount in water. Apply glycerine and watch for the result. What change is the protoplasm undergoing? Sketch the cell, showing the cell-wall and protoplasm.

C.—MORPHOLOGY OF THE FRUITING FILAMENTS.

(*a*) Observe the general appearance of the plant in its fruiting condition (*lp*), and note the marked contrast to the vegetative condition.

(*b*) Make a temporary preparation and observe the threads which have joined and are connected in pairs (**conjugating filaments**). Note the large round or oval bodies (**zygospores**) which are found in some of the cells.

(*c*) Carefully observe (*hp*) how the conjugating filaments are related and note the small tubes (**conjugating tubes**) which connect some of the cells. Do you find conjugating tubes between cells of the same filament?

(*d*) Do you find protoplasm in all the cells? What do you presume has become of the protoplasm of the cells which are now empty? How were the zygospores formed?

*NOTE.—If the plant has not been exposed to the sunlight within the preceding ten or twelve hours, starch grains may not be present.

(*e*) Examine a mature zygospore and note its shape, color, and the dense wall and contents. Sketch a portion of the two conjugating threads and represent the structural elements.

(*f*) Write a careful description of your observations of Spirogyra, and enumerate the points of resemblance and difference between Spirogyra and Protococcus.

OTHER WORK.

1. The life history of Spirogyra and its two methods of reproduction.
2. Comparison of Spirogyra with some of its allies, including Diatoms, Desmids, Oscillaria, etc.
3. Comparison of Spirogyra and Protococcus and the Yeast Plant.
4. A synopsis of the characteristics of Zygophyta and a list of the classes.

References. — 5 — 18 — 19 — 21 — 26 — 36 — 43 — 62 — 79 — 113 — 126 — 147 — 157 — 158 — 159.

STUDY III.

A STUDY OF A GREEN FELT.

VAUCHERIA SESSILIS.

As an example of the simplest bi-sexual plant. To represent the Oöphytes or egg-spore plants.

Material Required.—(1) Fresh Vaucheria; (2) Vaucheria preserved in equal parts 90% alcohol and glycerine. *Reagents.*—(1) Dilute glycerine; (2) iodine.

Habitat.

Vaucheria, or Green Felt, is an alga which appears as a large, dense, dark-green, felted mass of coarse, tubular, branching filaments. It may be found in almost every locality spreading over the mud in shallow ditches and on moist earth near springs, or floating on the surface of ponds and in quiet fresh water. Vaucheria may be found at all seasons of the year, growing on the soil in flower pots in the conservatories. Other species are quite as common as *V. sessilis*, and may be substituted for the latter in the following study.

LABORATORY WORK.

A.—GENERAL CHARACTERS AND GROSS MORPHOLOGY.

(*a*) Observe a mass of Green Felt on a flower-pot or culture plate, or in the water in an aquarium jar, and note its general appearance and color.

(*b*) Take a small tuft, and with your dissecting needles gently tease it out on the object-slide; mount in water and examine (*lp*).

(*c*) Note the size and appearance (*lp*) of the filament. Can you find transverse partitions (**septa**), marking off the tubular threads into cells?

(*d*) Trace one or more threads to determine the form of the natural tip. Sketch the tip, including a portion of the thread.

(*e*) Carefully search for branches that are given off from the main thread. How many kinds of branches can you find? How do they differ?

(*f*) If the Green Felt has been growing on soil, you may find root-like processes (**rhizoids**). Note their shape and size. Do they contain chlorophyll? Sketch a rhizoid, including a portion of the filament.

(*g*) Look for two short lateral outgrowths or branches of peculiar form, and near to each other on the filament. One is a curved, cylindrical body (**antheridium**), or male reproductive gonad, and the other an oval body (**oögonium**), or female reproductive gonad.*

B.—MINUTE ANATOMY.

(*a*) Examine more carefully (*hp*) the oögonium. Do you find a transverse septum which separates it from the protoplasms of the filament? Look for an oögonium which contains a thick-walled, oval reproductive body (**oöspore**), or ripe egg. Note the character of its protoplasm and surrounding cell-wall. Does it contain chlorophyll? Sketch the oögonium.

(*b*) Examine carefully (*hp*) the antheridium. Do you find a transverse septum similar to that of the oögonium? Note the appearance of the protoplasm of the antheridium, and its cell-wall. Does the antheridium contain chlorophyll? Sketch.

(*c*) Examine the protoplasm and other contents of the filament (*hp*). Do you find chlorophyll bodies, *chromatophores*, in Vaucheria? Note their form.

*In *V. sessilis* there are frequently two oögonia near the same antheridium. In some other species there are three to five oögonia associated with one antheridium and situated with the latter on a branch of considerable length.

(*d*) Observe the refractive bodies (**oil globules**) usually found abundantly among the chromatophores. Do you find nuclei.* Sketch (*hp*) a filament, carefully representing all its cell contents.

(*e*) Observe the thickness of the wall of the thread. Where is the protoplasm most dense? Apply dilute glycerine and note result.

(*f*) Apply test for starch and note result.

(*g*) Note that the form of the vegetable body (**plant body**) of Vaucheria is a *branched* thread or filament. What is the form of the plant-body in Spirogyra? In the Yeast Plant? In Protococcus? *Any plant body which has no true root, stem and leaves, is known by the name of thallus.*

(*h*) Write up a careful description of Vaucheria from your notes, and at the close make a summary enumerating all the points of resemblance and points of difference in Vaucheria and Spirogyra.

OTHER WORK.

1. The life history of Vaucheria and reproduction of oöspores and swarm spores.
2. Morphology of the thallus of Rockweed.
3. General morphology of Volvox, Water-mould, Mildew.
4. The nature of a fungus. Life-history and economic interest in the fungi belonging to the branch Oöphyta.
5. A synopsis of Oöphyta, and a list of the classes.

References. — 19 — 36 — 44 — 50 — 147 — 158.

* The nucleus in Vaucheria is seldom seen excepting after the use of special reagents.

† The uncertainty of the material renders it highly improbable that all the students of a class of considerable size should succeed in demonstrating the process of fertilization in Vaucheria, yet it is very desirable that it should be observed; hence it is thought best that the teacher should secure material in proper condition and give this demonstration in connection with the OTHER WORK named on this page.

STUDY IV.

A STUDY OF A STONEWORT.

*CHARA FRAGILIS.**

As an example of a highly organized alga. To represent the Carpophytes or spore-fruit plant.

Material Required.—(1) Fresh specimens of chara; (2) specimens preserved in alcohol; (3) specimens fixed in 0.2% chromic acid; (4) specimens of Nitella; (5) a set of the preparations of the apical cell; (6) a set of preparations of cross sections of the antheridium and oögonium.

Habitat.

The Stoneworts are plants of considerable size, consisting of simple jointed stems, bearing whorls of leaf-like structures, which are frequently only single rows of cells. They resemble the higher forms of plants, and are among the most highly developed of all the algæ. Their size varies with the species, from a few inches to three feet. They are submerged fresh-water plants, found along the sandy margins of lakes and ponds, and in swampy marshes and bog-holes, forming dense tufts of thread-like stems, and attached by rhizoids, or thread-like roots. With very little care these plants may be kept growing in the laboratory almost indefinitely.

* Chara fragilis is selected for this study on account of its abundance and general distribution; but the closely allied genus Nitella, is more desirable, on account of its greater simplicity of structure. The most prominent distinctions between Chara and Nitella are—Chara has leaves in whorls of 6 to 12 with leaflets always single-celled; Nitella has leaves in whorls of 5 to 8 with leaflets usually more than one-celled. The sporocarp has a crown of one whorl of cells; that of Nitella a crown of two whorls of cells. Chara has its stem strengthened by a firm internal crust of carbonate of lime. The stem and leaves in Chara contain a system of cortical cells; in Nitella no such system is present.

LABORATORY WORK.

A.—GROSS MORPHOLOGY OF THE THALLUS.

(*a*) Examine a fresh Chara in water in a white dish or over a piece of white paper. Observe its general appearance, and note how it affects the touch of your fingers.

(*b*) Observe the size and plan of the thallus. Note the joints (**nodes**) and the segments (**internodes**) between the joints (*m*). Are the internodes everywhere of uniform length? Observe the summit (**apex**) of the stem and its opposite end (**base**).

(*c*) Observe the circles (**whorls**) of thread-like organs (**leaves**) on the primary or main axis (**stem**) of the plant. Where, on the stem, are the leaves inserted? Do you find any exceptions to your answer? How many leaves in the same whorl? Note the cluster of leaves (**apical bud**) crowded together at the apex of the stem. Sketch a portion of the stem including two nodes and two internodes (× 2).

(*d*) Examine the stem at the nodes above the whorl of leaves, and note whether you find small shoots or secondary axes (**branches**). Note that the branches are inserted in the angle formed by the leaf and the stem (**axil of leaf**). Sketch a branch.

(*e*) Examine a leaf (*m*). Of what does its main axis consist? How many internodes do you find in the larger leaves? Note the delicate thread-like structures (**leaflets**) attached to the main axis of the leaf. Where are the leaflets inserted? Sketch a leaf and its leaflets (*del.* 2′).

(*f*) Observe (*m*) that on some leaves (**fertile leaves**) there are yellowish or orange-colored* structures, the reproduct-

* In alcoholic specimens the natural colors are not preserved.

ive gonads, which are arranged in pairs. Do you find some leaves (**sterile leaves**) on which no such structures appear?

Examine the gonads, and note that one, the male gonad (**antheridium**), is inserted below the whorl of leaflets, and the other, the female gonad (**oögonium**), above the whorl of leaflets. Describe the shape of the gonads and compare them in color. Sketch a portion of a fertile leaf, representing a pair of gonads and the adjacent leaflets (*del.* 2′).

(*h*) Observe (*m*) the delicate hair-like filaments or *rhizoids* attached to the lower portion of the stem. Where are they inserted? Do the rhizoids contain chlorophyll? Sketch.

B.—MINUTE ANATOMY OF THE THALLUS.

(*a*) Mount a portion of the stem in water and examine it (*lp*). Observe the internode and note the surface or outer layer of cells (**cortical cells**). How are they arranged? Sketch a patch of cortical cells (*del.* 1½′).

(*b*) Examine a cross section* of the stem (*lp*) and note the cortical cells and a large central cell (**internodal cell**). Sketch (*del.* 1′).

(*c*) Examine a longitudinal section passing through one of the nodes (*lp*). Observe the cells at the nodes (**nodal cells**). How are they related in position to the internodal cells? Sketch.

(*d*) Examine a fresh sterile leaf (*lp*) and observe the *nodal* and *internodal* cells and the large end cell (**terminal cell**). Compare the plan of the leaf with that of the stem. Sketch a portion of the leaf including the terminal cell.

*The student may here be taught to make hand sections with a sharp razor, or the instructor may have the sections cut in advance, and supply them to the class.

(*e*) Examine a fresh leaflet (*hp*) and identify the *cell-wall*, *protoplasm*, *chlorophyll granules*, *vacuoles*, and *nucleus*. Sketch a leaflet representing these structures.

(*f*) Examine a terminal cell of a good fresh specimen (*hp*) to observe the movement of the protoplasm.* Focus carefully into the central region of the cell, and study the directions of the different currents. Sketch an outline of the cell wall and represent the currents by dotted lines, and their directions by darts.

(*g*) Examine (*hp*) a preparation of a longitudinal section through the apex of the stem, and study the size and arrangement of the end cells. Note the large, nearly hemispherical cell (**apical cell**) at the end of the stem. Sketch the apical cell with the adjacent cells.

C.—MORPHOLOGY OF THE GONADS.

(*a*) Examine a fresh, mature spermary, or antheridium (*lp*). Note the stalk by which it is attached to the leaf. Study the surface and note the large flat cells (**shields**), which form the wall of the antheridium. Note the outline and margin of the shield-cells. Sketch the antheridium, representing the shield-cells.

(*b*) Remove the cover-glass, crush the antheridium slightly and tease it out with your needle and mount in water. Study the contents and make out, if possible, the cylindrical cell, or handle (**manubrium**) attached to the inner surface of the shield-cell. The manubrium may have been broken off in the process of making the preparation; if so, the thicker end is the one which was attached to the shield. Now study (*hp*) the

* The stamen hairs of Tradescantia will show the movement of protoplasm very satisfactorily, in case sufficiently fresh specimens of Chara cannot be obtained when needed. Nitella is more favorable for studying the rotation of protoplasm than Chara.

opposite or distal end of the manubrium, and note the short cells (**head cells**) attached to it. Sketch a shield and a manubrium with its head-cells.

(*c*) Study (*hp*) the tangled mass of delicate thread like structures (**spermatic filaments**) which have been pressed from the interior of the antheridium. Some of the filaments may still retain their original attachment to the head-cells. Represent several filaments in your last sketch.

(*d*) Study a favorable filament and decide whether it is composed of a single cell or more than one. If the antheridium is fully mature and in good condition, you may be able to discover minute, coiled, lash-like cells (**sperm cells** or **spermatozoids**). By careful focusing, study the exact shape of a spermatozoid. Sketch a spermatic filament and a sperm, if you have found one.

(*e*) Mount a mature ovary or oögonium in water and study (*lp*) it. Note its short stalk. Observe the form and snrface structure of the oögonium. At its distal end note the chimney-like circle of cells (**crown**). Do you find more than one circle of cells in the crown? How many crown cells are there?

(*f*) Observe the large opaque structure in the centre of the oögonium. Sketch the oögonium, representing carefully the surface appearance and crown.

(*g*) If possible, study preparations of cross-sections of the gonods, and identify the structures already seen bearing in mind their relative position. Sketch a cross-section of each gonad.

(*h*) Write a description of the morphology of Chara, and make careful drawings of the principal structures.

OTHER WORK.

1. Comparative review of the morphology of Chara and Vaucheria.
2. The life history of Wheat-rusts, Smuts and Black Knot; their migration and parasitic habits.
3. The mode of vegetation and reproduction in such saprophytic fungi, as Mushrooms, Puffballs, etc.
4. The peculiarity of Lichens.
5. Sexual and non-sexual reproduction in Carpophyta.
6. A synopsis of the characteristics of Carpophyta, and a list of the classes.

References.—5—12—17—18—19—20—21—23—26—35—43—44—46—50—62—73—74—79—126—147—149—153.

STUDY V.

A STUDY OF A LIVERWORT.

MARCHANTIA POLYMORPHA.

As an example of a highly differentiated thalloid plant which at the same time retains a remarkable degree of simplicity. To represent the mossworts or Bryophytes.

Material Required.—(1) Fresh vegetative thalli and both kinds of reproductive branches; (2) gemmæ growing in a phial of water; (3) a set of preparations of the antheridium; (4) a set of preparations of archegonia in different stages of development.

Habitat.

Marchantia is a small, green, flattened, creeping plant whose thallus or vegetative body consists of a leaf-like stem about a half an inch wide and from one to four inches long. The reproductive branches are umbrella shaped, consisting of a slender upright stalk supporting a flat disc. Marchantia bears the male and female branches on different plants, and is therefore *diœcious* in distinction from plants which bear both male and female gonads in the same plant and are known as *monœcious*. The thallus is closely attached to the soil by a large number of silken rhizoids. Marchantia is common to all parts of the United States. It grows preferably in moist soil, on shaded rocks, walks, and fences, sometimes it may also be found along old roads and among the grass in exposed places. It should be transported to the laboratory attached to the soil, and may be kept indefinitely in a moist chamber, if protected from the direct rays of the sun. A closely allied form, Lunularia, can always be had at a greenhouse and may be distin-

guished from Marchantia by the form of its gemmule cups; in the latter plant the rim of the cup is a complete circle, while in Lunularia it is incomplete, leaving the outline somewhat crescent shaped

LABORATORY WORK.

A.—GROSS MORPHOLOGY OF THE THALLUS.

(*a*) Observe a Liverwort while it is still attached to the sod from which it grew. Note the general appearance of the plant; its flattened horizontal thallus and firm attachment to the sod.

(*b*) Observe particularly the size and shape of the thallus, and note its horizontal *branches*. Does the thallus consist of nodes and internodes? Name the points of resemblance between the main thallus or stem and its branches.

(*c*) Observe the indented apex of the vegetative thallus and note its mode of branching (**dichotomous**), by which it first diverges into two equal branches, but one soon develops more rapidly than the other and becomes the main axis or stem.

(*d*) Examine (*m*) the vegetative thallus and observe the distinctly marked median line (**midrib**) which is the main axis of the stem or thallus. Note also the expansion of the thallus (**wings**) which extend along either side of the midrib.

(*e*) Do you find any branches (**fruiting branches**) which are umbrella-shaped? What is their attitude and where are they inserted on the main thallus? Note the erect stalk (**pedicel**) and flattened disc (**receptacle**) of which the fruiting branches are composed.

(*f*) Observe the little cups (**cupules**) which are almost certain to be seen on the upper surface of the vegetative

thallus. Observe (*m*) their exact shape, and note the small flat structures (**gemmæ**) within the cupules. Sketch a cupule.

(*g*) Observe the silken rhizoids of the thallus. Where are they given off? Mount a few in water and examine (*lp*). Do you find more than one kind? Sketch.

(*h*) Observe (*m*) the overlapping *scales* on the under surface of the thallus. These thread-like scales and the rhizoids are forms of plant-hairs (**trichomes**). Mount a few scales in water and observe (*lp*) their structure. Do you find more than one kind? Sketch.

B.—MINUTE STRUCTURE OF THE THALLUS.

(*a*) Examine the upper surface (*m*) of an older portion of the thallus and observe the small areas (**areolæ**), and in the center of each a small breathing pore (**stoma**).

(*b*) Remove a thin portion from the upper surface tissue of the thallus and mount it in water. Study (*lp*) this surface layer of cells (**epidermal cells**) and note their shape and contents.

(*c*) Study a stoma and observe (*lp*) the cells (**guard cells**) which surround it. How many guard cells are there and how are they arranged? Sketch a stoma with its surrounding cells.

(*d*) Study a cross section of a thallus (*lp*) and note the different kinds of cells. Near the margin, identify the upper epidermal cells. Look along the epidermal layer for a stoma. Carefully focus and make out the number and arrangement of the cells which form it.

(*e*) Examine the large chamber (**air-chamber**) into which the stoma leads. Note the chains of cells (**chlorophyll cells**) which grow from the bottom of the air-chamber. Note

the shape and contents of the chlorophyll cells. Sketch a chain of chlorophyll cells.

(*f*) Observe the thickened and closely packed cells (**parenchyma**) which form the sides and bottom of the air-chamber. Note the shape and contents of these cells. Sketch several adjacent parenchyma cells.

(*g*) Examine the layer of epidermal cells on the under side of the thallus. How do they differ from those in the upper layer? Do you find any stomata? Sketch a few adjacent cells of this layer.

(*h*) Study your section in the region of the midrib. Identify the rhizoids, and among them the flat purplish structures (**scales**). Note the form and arrangement of the cells in the scales. Sketch one or more rhizoids and scales.

C.—MORPHOLOGY OF THE FRUITING BRANCHES.

(*a*) Examine (*m*) a male branch with the shield-shaped, scalloped receptacle (**antheridial branch**). Observe the general shape, margin and color of the receptacle. Note the minute *antheridia* imbedded in its upper surface. Sketch the antheridial branch (*del. 2'*).

(*b*) Observe the upper and lower surfaces of the receptacle (*m*). Note the *rhizoids* and *leaf-like scales*. Where are these inserted? What resemblance do you find between the fruiting and vegetative thalli? Compare the upper surfaces; the lower surfaces.

(*c*) In a vertical section, cut in the plane of the stalk, observe (*lp*) the large cavities (**antheridial sacs**) and note their contents, the *antheridium*. Sketch a favorable portion of the section; also make a separate sketch of an antheridium as seen in the antheridial sac.

(*d*) Examine (*m*) the female branch with the spreading,

strap-shaped rays (**archegonial branch**). Note the general shape of the disc, the number of its rays and the color.

(*e*) Examine (*m*) the under side of the receptacle and note the peculiar *grooves* radiating from the stalk. How are these grooves related to the rays in regard to position?

(*f*) Observe the form of the stalk and note its deep, longitudinal furrow. Sketch the archegonial branch (*del.* 2′).

(*g*) Carefully examine (*m*) the grooves in the under side of the receptacle, and note their contents. With your scalpel carefully remove the contents of one of the grooves and mount in water, and examine (*lp*). Note the flask-shaped organs (**archegonia**).

(*h*) Examine a well developed archegonium and note its three regions,—(1) the short *stalk*, (2) the ventral portion or *body*, and (3) the tubular portion or *neck*. Observe also in the central region a spherical body (**oösphere**). Sketch an archegonium, representing carefully any cell-boundaries which you have been able to make out (*del.* 2′).

D.—MORPHOLOGY OF THE GEMMA.

(*a*) With the point of your scalpel remove one or two gemmæ from the cupule and mount in water. Observe (*lp*) their form and general appearance. Note the two deep notches (**vegetative notches**) on opposite edges, and the *scar* where the pedicel was attached. Sketch outline of gemma (*del.* 1′).

(*b*) Observe the cellular structure of the gemma. Do you find chlorophyll? Where is chlorophyll not present? Note the *oil-bodies* in the cells along the edge. Do

you find cell boundaries? Represent the cellular structures in your outline sketch.

(*c*) Examine (*lp*) a gemma which has been growing in a phial of water for about a week. Study the changes which have taken place. Make a careful sketch of the gemma (*del.* 1½′).

(*d*) Write a description of the morphology of Marchantia and make careful drawings of the more important structures of the plant.

OTHER WORK.

1. Comparative review of the morphology of Marchantia and Chara.
2. The function of the stomata, air-chambers, rhizoids, etc.
3. The life-history of Marchantia. Reproduction by gemmæ.
4. The general morphology of a Moss.
5. Comparative review of the thallophytes and lower cryptogams.
6. A synopsis of the characteristics of Bryophyta and a list of the classes.

References. — 5 — 12 — 17 — 18 — 19 — 21 — 26 — 44 — 95 — 126 — 147 — 154.

STUDY VI.

A STUDY OF A COMMON FERN.

*PTERIS AQUILINA.**

As an example of a vascular cryptogam, or higher flowerless plants. To represent the Fernworts, or Pteridophytes.

Material Required.—(1) A set of fresh specimens in fruiting condition; (2) alcoholic specimens; (3) prepared sections of the stem; (4) prepared sections of the root; (5) prepared sections of the stipe; (6) prepared sections showing the cellular structure of the leaf; (7) germinating spores; (8) prothallia.†

Habitat.

The common Bracken or eagle-fern (*Pteris aquilina*) is one of the most widely distributed of the higher plants. In the United States it occurs under various conditions, being found in densely shaded groves, in open woodland among the undergrowth, on the hillside, and in open pastures. In general, however, it favors damp, shady places. While in some countries it grows to the proportions of a tree, throughout the northern United States it does not usually exceed the height of from two to three feet. The Common Bracken lives from year to year (**perennial**). In cold climates the leaves (**fronds**) die to the ground at the close of each season, while the underground stem (**rhizome**) survives the winter and sends forth a new set of fronds in the spring.

In the course of its reproduction, the Fern passes through

* Any species of Pteris, and in fact most any common Fern may be substituted for the one here named.

† It is desirable to have the sets of preparations on hand, even if the student is required to make his own.

a cycle of two generations (**alternation** of **generation**), representing a non-sexual plant (**sporophore**) and a sexual plant (**oöphore,** or **prothallium**). The sporophore is the conspicuous fern-plant generally known, and bears on the lower surface of its frond minute seed-like structures (**spores**) which are capable of germinating and developing into the oöphore or true sexual plant. The oöphore or prothallium, as it is usually called, is a small, inconspicuous, cushion-like plant which bears minute antheridia and archegonia, whose product after fertilization develops into the sporophore or the well-known fern-plant.

The Fern is the lowest plant Type which represents all the *members*, or parts of the *plant body* found in higher plants, *viz.:* a true *root*, *stem*, *leaves* and *trichomes*. In the Fern we meet for the first time with true woody (**fibro-vascular**) tissue. Material necessary for studying the Fern can usually be found in the green-houses throughout the year, if the necessary stock is not available from other sources. The spores of most Ferns retain their vitality for more than a year and may be kept dry until needed. For germination the spores of the lady fern (*Asplenium filix-fœmina*), or those of the ostrich fern (*Onoclea struthiopteris*) will perhaps prove most satisfactory. The spores may be sown on clean, moist sand, or on porous earthenware and kept under a bell-jar. With favorable conditions germination will begin in four or five days.

LABORATORY WORK.

A.—GENERAL MORPHOLOGY OF THE FERN-PLANT (SPOROPHORE).

(*a*) Observe the general appearance of the Fern-plant. Which parts belong below and which above the surface of the ground? Note the attitude or directions in which these parts extend. Note the color of the different parts of the plant.

(*b*) Examine the brown underground stem (**rhizome**), and note its form, size and direction. Note the light line (**lateral line**) extending along each side. Do you find nodes and internodes in the rhizome?

(*c*) Observe the slender appendages (**roots**) springing from the rhizome. Note the general appearance of the roots; their size as compared with the rhizome; their branches and color. Have the roots any definite arrangement and where are they attached? Do you find rhizoids?

(*d*) Observe the green spreading leaves (**fronds**) arising from the rhizome. Note that the frond consists of a leaf-stalk or main axis (**stipe**) and the blade or leaf proper (**lamina**) which is subdivided like a feather (**pinnate**) into a number of larger lobes (**pinnæ**) which are again subdivided into still smaller lobes or leaflets (**pinnulæ**). Note that each pinnule or leaflet has a thickened axis or central rod, the *midrib*, extending through its blade. Note the branches (**veins**) given off by the mid-rib.

(*e*) Again, observe the surface of the rhizome and note the decaying stipes, and scars where older stipes were attached. Examine and compare the ends of the rhizome, and note the large buds, *apical buds*, growing at one end. What do you infer to be the habit or manner of growth of the rhizome?

(*f*) Do you find thin, brown leaf-scales* (**ramenta**) covering portions of the surface of the rhizome. What do you infer to be the function of the ramenta?

3.—MORPHOLOGY OF THE RHIZOME.

(*a*) Examine (*m*) a cross section† of a rhizome of medium size and note the general outline and appearance. Can you recognize the *lateral lines?* Sketch outline (*del.* 2).

* Some other species of Ferns develop the ramenta more than Pteris.

† There is some advantage in using sections not stained for par. *a, b, c.*

(*b*) Study the interior of the section (*m*) and note that it consists of different regions or bands of tissue. How many kinds of tissue can you distinguish?

(*c*) Observe (*m*) the (1) outer dark band or system of tissue, *epidermis;* (2) the strands of tissue which form an incomplete brown ring (**sclerenchyma**) in the interior; (3) the scattered strands and circles of yellowish tissue (**fibro-vascular bundles**); and (4) the lighter colored tissue, *parenchyma*, which everywhere surrounds the last two named systems. Now represent in outline these systems in your sketch for (*a*), p. 142.

(*d*) Observe that the smaller fibro-vascular bundles are arranged in an outer circle, and that the large strands are located between the bands of sclerenchyma and near the center of the outer circle.

(*e*) Examine more carefully (*lp*) a stained cross section of the rhizome, and study the epidermis. Note the outer layer of thickened cells, the *epidermis proper*, and that inside of this layer the epidermal system gradually blends into the parenchyma.

(*f*) Do you find that the epidermis gives off trichomes at different points? Are these trichomes many-celled or single-celled? Note the leaf-sheath, or ramenta, if you find them represented in your section. Make a sketch of a portion of the epidermis in a favorable region including one or more trichomes (*del.* 1½′).

(*g*) Examine (*lp*) the strands of sclerenchyma. Can you find small patches of sclerenchyma outside of the main strands? Note the thick-walled cells of which the sclerenchyma is principally composed. Sketch a small portion of this tissue (*del.* 1½′).

(*h*) Examine (*lp*) the fibro-vascular bundles. Note that the cells which constitute its border are arranged

in two layers or rows,—the outer row (**bundle sheath**) consisting of small flattened cells, and the inner row (**phloem sheath**) of somewhat larger cells and containing starch. Note that within this double sheath there are several kinds of cells and tubes (**vessels**). Note the large tubes with woody walls (**scalariform vessels**). Sketch a portion of a fibro-vascular bundle, representing the various kinds of cells and vessels (*del.* 1½′).

(*i*) Examine the fundamental tissue or parenchyma and note the form and contents of the cells. Does it contain Starch? Sketch a portion (*del.* 1½′).

C.—MORPHOLOGY OF THE FERTILE FROND.

(*a*) Examine (*m*) a cross section of the stipe and compare it with that of the rhizome. What systems of tissues do you find represented in the stipe? Do you find trichomes. Sketch the section (*del.* 1).

(*b*) Remove a small patch of epidermis from the lower surface of the blade and mount in water. Observe (*hp*) the shape of the epidermal cells. Note their nuclei. Do you find trichomes? Sketch one or more trichomes.

(*c*) Examine (*lp*) the stomata, and note the form of the guard-cells. Compare the stomata of Pteris with those of Marchantia. Sketch a stoma with its surrounding epidermal cells.

(*a*) Examine (*m*) the margin of a fertile leaflet or pinnule (**sporophylla**) and observe that its edge has folded under, forming a hem or tube, *receptacle*, along the margin.

(*e*) Observe (*m*) shape of the lid-like cover (**indusium**) formed by the incurved edge of the pinnule.

(*f*) Examine (*lp*) a small portion of the receptacle and observe a row or ridge (**sorus**) to which are attached minute oval bodies (**sporangia**). Sketch a portion of the receptacle, showing indusium, sorus, and sporangium.

(*g*) Examine (*m*) a preparation of sporangia, and observe their general shape and appearance. Observe that a sporangium consists of a globular portion (**capsule**) and a short stalk, *pedicel*. Sketch.

(*h*) Examine (*lp*) an unbroken sporangium, and observe the shape and arrangement of the cells. Note the row of dark cells (**annulus**) in the margin of the capsule. Does the annulus extend along the entire margin? Sketch a sporangium representing the cells.

(*i*) Examine a capsule in which you find the wall broken and its contents set free. Where, with reference to the annulus, did the wall of the capsule rupture? What do you presume is the function of the annulus? Sketch a sporangium with ruptured capsule.

(*j*) Examine (*hp*) the minute seed-like, reproductive cells (**spores**) which have escaped from the ruptured sporangium. Note their form and appearance. Sketch a few spores.

D.—MORPHOLOGY OF THE PROTHALLIUM (OÖPHORE).

(*a*) Examine (*lp*) some germinating spores and observe their ruptured coverings. Note the blunt cylindrical protrusion (**protonema**) which is the first appearance of the young plant. Do you find one or more rhizoids attached to the protonema?

(*b*) Carefully observe and note the number of cells in the protonema. Examine others. Describe the cellular structure. Sketch a favorable protonema.

(*c*) Mount in water and examine (*m*) the young plant

which has developed from a protonema (**oöphore** or **prothallium**). Observe its size, shape, and general appearance. Note the rhizoids. Sketch the prothallium.

(*d*) Examine (*lp*) the prothallium with its lower surface upward and note the shape of the cells and their structure. Sketch the outline of the prothallium, representing a few cells along the margin (*del.* 1½′).

(*e*) Carefully focus and examine the central region of the prothallium and look for small spherical gonads, *antheridia*, which usually develop from the surface of the prothallium in the region where the rhizoids are attached. Look for the other kind of gonads, *archegonia*, usually situated nearer the notch (**sinus**) of the prothallium. If you have been able to find the antheridia and archegonia, represent them in your sketch of the prothallium.

(*f*) Write up a description of the Bracken Fern and make careful drawings of the principal structures of the sporophore and oösphore.

OTHER WORK.

1. The life-history of the Fern.
2. Comparative review of the Fern and Marchantia.
3. Characteristics of Equisetum, Fern, and Club-moss.
4. Trichomes and the development of spores.
5. A synopsis of the characteristics of Pteridophyta.
6. Comparative review of the types of cryptogams, with special reference to the development of root, stem, leaves, and trichomes.
7. Comparative review of cryptogamic types with reference to sexual reproduction.

References. — 5 — 6 — 10 — 12 — 17 — 18 — 19 — 20 — 21 — 26 — 43 — 44 — 62 — 68 — 79 — 126 — 137 — 147 — 155.

STUDY VII.

A STUDY OF A SCOTCH PINE.

PINUS SYLVESTRIS.

As an example of the lower form of seed-plants. To represent the Gymnosperms.

Material Required.—(1) Male flowers fresh and preserved in alcohol; (2) female flowers fresh and preserved in alcohol; (3) succulent cones preserved in alcohol; (4) ripe cones dry; (5) ripe seeds dry; (6) young roots preserved in alcohol; (7) leaves fresh and preserved in alcohol; (8) two-year-old branch in alcohol; (9) fresh twigs.

Habitat.

The Scotch Pine, sometimes wrongly called "Scotch Fir," is one of the most familiar of our cultivated "evergreens." It is a tree of moderate size, and at least while young, of beautiful symmetry. The trunk continues through the central part of the tree to the highest point, and can be readily distinguished from the branches; this characterizes it as *excurrent*, in distinction from one which is lost by subdivision into its branches, and is known as a *deliquescent* trunk. The bark of the trunk and main branches is rough and scaly and of a brownish color. The foliage consists of needle-shaped leaves which are arranged in pairs and are from five to ten centimeters in length, slightly twisted, and covered with a whitish powder. The Scotch Pine bears two kinds of reproductive branches, known as the male flowers, and the female flowers; the former are conspicuous yellow clusters which are borne at the base of young shoots; the latter are inconspicuous pinkish oval clusters which project slightly beyond the ends of young shoots.

The cones, or "fruit," of the Scotch Pine are only from five to twelve centimeters in length, and require two years to develop.

The Scotch Pine represents the lower of the two great classes of "seed plants" or *Spermaphyta;* it belongs to the class Gymnospermæ, or "naked-seeded" plants, the seeds or ovules being borne in open *carpophylls*. The other great class, including the highest of all plants, the Angiospermæ, or "covered-seeded" plants, in which the carpophyll forms a closed cavity known as the *ovary*. The Pines are of very great importance on account of their valuable timber, turpentine, and resinous secretions.

The Scotch Pine and Austrian Pine bear a close resemblance, but the following characteristics of the Scotch Pine will distinguish it from the Austrian: the Scotch Pine has smaller leaves; leaves covered with a whitish powder; free end of cone scales terminate in protuberances; cones smaller than in Austrian Pine. The Austrian Pine is a good substitute in this study.*

LABORATORY WORK.

A.—GENERAL MORPHOLOGY OF THE SCOTCH PINE.

(*a*) Observe the general form and appearance of the Scotch Pine. Note its central stem or trunk, and the arrangement of the large branches along the stem. Is the trunk a central shaft (*excurrent*) readily traced to the apex or highest point of the tree; or is it lost by subdivision into its large branches or secondary trunks (*deliquescent*)?†

*The proper time for collecting ripe male and female flowers is about June 1; the large cones and those of less than a year old may be collected during the early spring.

†The student will hardly fail to find access to Scotch or Austrian Pines or other conifers in the parks of the vicinity, and should be encouraged to make these observations of the form and appearance of the tree. He should at the same time compare the Scotch Pine with other "evergreens," and with other trees. If possible, all of Sec. A. of this study should be outdoor work.

(*b*) Observe the main branches given off by the trunk. Are they few or numerous? Make a diagram representing the trunk and the arrangement of the main branches (*del. 2'*).

(*c*) Examine a branch of this season's growth with its leaves (**shoot**). Can you recognize a shoot of last season's growth? A two-year-old shoot?

(*d*) At the apex of a shoot observe the large *apical bud* and several smaller ones (**lateral buds**), which are undeveloped branches. Note the scales-leaves which constitute the covering of the bud. Sketch the apical bud, including the lateral buds (× 2).

(*e*) Examine the condition and appearance of the bark on the trunk and main branches. Observe the scales (**scale-leaves**) on the branches, and compare them on shoots of different ages.

(*f*) Examine a small branch and observe the very short branches (**dwarf branches**) which bear the leaves. Note the green needle-like leaves (**foliage leaves**). How many foliage leaves are borne on each dwarf branch? Find the average length in centimeters of six or eight foliage leaves.

(*g*) Observe the scale leaves at the base of the foliage leaves. How are they arranged? Note the black sheath which binds the base of the foliage leaves together. Sketch a dwarf branch representing the scale leaves and foliage leaves.

B.—MORPHOLOGY OF THE FOLIAGE LEAF.

(*a*) Observe carefully the shape of the foliage leaf, its proximal or attached end (**base**) and its distal end (**apex**). What is the shape of the apex? Pass your finger from the apex toward the base. What do you observe?

(*b*) Examine (*m*) the edge of the leaf and note your observation. Draw a leaf between your thumb and finger and note that it is covered by whitish, waxy bloom or powder (**glaucous**). Do you know of any other plant whose leaves are glaucous?

(*c*) Examine (*m*) the sides of the leaf and decide which is the upper side. Note the series of small dots, the *stomata*. Sketch a portion of the leaf representing the edge, surface, and position of the stomata (×3).

(*d*) Examine (*lp*) a cross section of foliage leaf and observe its outline. Which margin represents the upper, and which the lower side of the leaf? Sketch the outline of the section (*del.* 1½′) and indicate which is the upper and which is the lower side.

(*e*) Identify (*lp*) the *epidermal tissue*, *bundle sheath* enclosing two *fibro-vascular bundles*, and represent these in your outline sketch.

(*f*) Observe (*lp*) the small openings (*resin passages*), surrounded by a circle of thick-walled cells. Represent the resin passages in your sketch.

(*g*) Examine (*lp*) carefully the fibro-vascular bundles, and note that each consists of two nearly equal parts,—one the woody tissue (**xylem**) and the other the bast (**phloëm**). Which is toward the upper and which toward the lower surface of the leaf? Sketch a fibro-vascular bundle, representing and labeling the *xylem* and *phloëm* (*del.* 1′).

C.—MORPHOLOGY OF A YOUNG BRANCH.

(*a*) Examine a cross-section of a two-year-old branch, and study its structure. Of how many different rings of tissue does it consist? Observe the central region of parenchyma (**pith**). Note its outline and structure.

(*b*) Observe the outer zone of tissue (**bark**), and note its structure. Note the row of large *resin ducts* which extends through the bark.

(*c*) Study the zone of firm xylem tissue extending between the bark and the pith (*wood*). Do you find that this zone of wood is marked off into two concentric zones (**rings of growth**). What do you presume in regard to the comparative age of these rings of growth?

(*d*) Observe the many radiating lines extending from the pith to the bark (**medullary rays**). Observe their origin at the edge of the pith. Note the small resin ducts in the wood. How are they arranged? Sketch the section showing the different tissue systems (*del.* 1½′).

(*e*) What points of similarity have you discovered between the structure of the leaf and that of the branch?

D.—MORPHOLOGY OF THE STAMINATE OR MALE BRANCH.

(*a*) Examine a young branch which contains at its base a compact cluster of small, lateral, sporophyll-bearing branches (**flowers**). Observe that each flower is a yellow, scaly, cone-like body. Note the arrangement of the flowers along the main branch (**inflorescence**).

(*b*) Observe the general outline of the inflorescence. Note that the flowers are *sessile* in their attachment to the branch (**catkin** or **spike**).

(*c*) Do you find foliage leaves on the staminate shoot? Note their position. Where along the main axis do you find scale-leaves? Sketch a staminate shoot, representing the inflorescence, foliage leaves, and scale leaves (*del.* 2′).

(*d*) Carefully remove one of the flowers from its flower cluster or spike, and observe (*m*) its form and structure.

Note that it is composed of scale-like sporophylls (**stamens**) arranged along a central axis. Sketch a flower ($\times$ 2).

(*e*) With your forceps remove one or two of the stamens, mount in water and examine (*lp*). Observe its general shape, its base and apex. Has it a foot-stalk (**filament**) or is it sessile?

(*f*) Observe (*lp*) two swollen sacs, the *sporangia* (**pollen sacs**) on one side of the stamen. Look for their contents, the *spores* (**pollen grains**).*

(*g*) Are the sporangia on the outer (lower) or inner (upper) side of the stamen or sporophyll?

(*h*) Examine (*hp*) a preparation of the pollen grains, and observe its general shape and appearance. Note the central cell and the two lateral wing-like protrusions. Can you distinguish a nucleus? Sketch a pollen grain (*del.* 1′).

E.—MORPHOLOGY OF THE PISTILLATE OR FEMALE BRANCH.

(*a*) Examine a young shoot containing pistillate branches, and look for small, brown, scaly structures, the sporophyll-bearing branches (**female flowers** or **cones**). How many of these flowers or cones do you find? Where, with reference to the dwarf branches, are the cones situated?

(*b*) Observe (*m*) the form and general appearance of the female flower. Has it a stalk (**peduncle**), or is it sessile? Sketch a portion of the vegetative branch, including a dwarf branch and a cone.

(*c*) Observe (*m*) that the cone is composed of a large number of thickened fruit-scales or female sporophylls (**carpels**), which are provided with a prominent me-

* The pollen sacs may already have opened and the pollen escaped.

dian projection (**keel**). Is the keel on the upper or lower surface of the carpel? Note the thin scales (**bracts**). Where are they situated?

(*d*) Examine (*lp*) a preparation of carpels, and observe at the base of the keel two enlargements (**ovule**) or undeveloped seeds. Can you detect a small opening (**micropyle**) leading into each ovule? Sketch a carpel showing the keel and the ovules.

(*e*) Examine a yearling cone and observe its color, size, and shape. Observe the distal free ends of the carpellary scales. Sketch.

(*f*) Examine a longitudinal section of a yearling cone. Observe the central axis and the ovules along its sides. Identify the bracts and carpels, and note their relative thickness. Sketch.

(*g*) Examine a two-year-old cone which is now mature and ready to scatter its ripened ovules (**seeds**). Observe its size and color. Observe the size of the carpels, and note the markings on their exposed distal ends.

(*h*) Observe the spiral arrangement of the carpels on the central axis. In about the thickest part of the cone select a carpel, and with your pencil mark it "a." Now find one that is situated in line directly above this, and mark it "b." Beginning at "a" trace the spiral row of carpels around the cone until you reach "b," and note how many revolutions of the cone you have made. Now return and, beginning again with "a," count the carpels which you passed over before reaching "b." Write the number of revolutions as the numerator of a common fraction, and the number of carpels as the denominator. This fraction expresses the law or order of the arrangement of the

carpels or sporophyll on the axis (**phyllotaxy**), and is the method used for indicating the rank or arrangement of leaves on the stem.

(*i*) Study a carpel which has been removed from the cone, and note its color, shape and woody structure. On the upper side note the two depressions where the ovules were situated. Sketch the upper and the lower view of the carpel.

(*j*) Examine the fully matured ovule or *seed*, and observe its shape and appearance. Note the wing-like expansion and the surface markings. What function do you attribute to this expansion? Sketch a seed

OTHER WORK.

1. Pollination and Fertilization in the Pine.
2. Life-history of the Scotch Pine.
3. Comparative review of the morphology and reproduction in the Scotch Pine and Fern.
4. The nature of a seed contrasted with that of a spore.
5. The characteristics of different types of Gymnosperms.
6. A synopsis of the characteristics of Gymnospermæ and a list of the orders.

References. — 4 — 5 — 18 — 19 — 43 — 68.

STUDY VIII.

A STUDY OF A TRILLIUM.

TRILLIUM RECURVATUM.

As an example of a lower, typical flowering plant with seeds enclosed in an ovary. To represent the class Angiospermæ.

Material Required.—(1) Fresh plants (entire) in bloom; (2) alcoholic specimens of roots, stems, flowers, and fruit; (3) sets of preparations showing cross sections of stem, roots, and fruit.

Habitat.

Trillium is a representative of the Lily order, one of the lowest of the class Angiospermæ. It is easily recognized by its naked "stem," from eight to thirty centimeters in height, bearing a whorl of three broad, netted-veined leaves and a single flower. The stem is an underground root-stock or rhizome, and sends up annually a single branch which dies to the ground at the close of the season. Trillium develops a flower of the typical kind, consisting of floral envelopes and reproductive organs in sets of modified leaves, arranged in whorls on the expanded apex of a short branch. The Trillium is found generally throughout the United States. The species named above, *T. recurvatum*, occurs in rich, damp woods, and blooms in the early part of May, the time varying slightly with locality and season. Any species may be used in this study.

LABORATORY WORK.

A.—GENERAL MORPHOLOGY OF TRILLIUM.

(*a*) Examine a fresh specimen of the entire plant. Observe the underground stem or rhizome, the part above

ground, its aërial branch. Note the size and general appearance of the Trillium plant.

(*b*) Examine the stem and observe its nodes and internodes. Can you find lateral or terminal buds? Do you find scales or any modification of leaves?

(*c*) Observe the character of the roots. Where are they attached? How many for each node? Do they give off branches? Sketch the rhizome and its roots (*del.* 2′).

(*d*) Observe the aërial branch, and note its size and color. Does it consist of nodes and internodes? Observe the scale leaves at the base of the branch, and note their form and structure (*m*). Where are they attached? Sketch.

(*e*) Observe the whorl of leaves at the distal end of the aërial branch, and note their number, form, size, and arrangement on the branch. Observe the flower above the whorl of foliage leaves, and note its form and color. Sketch the aërial branch, including the leaves and flower (*del.* 2½′).

B.—STRUCTURE OF THE STEM AND AËRIAL BRANCH.

(*a*) Study (*lp*) a cross section of a portion of the rhizome, and observe the systems of tissue. Note the very narrow *cortical* band of tissue along the margin, the fundamental parenchyma, containing a large amount of food material and the scattered *fibro vascular* bundles. Sketch a portion of the section representing the different kinds of tissue.

(*b*) Study (*lp*) a longitudinal section taken through the growing tip of the rhizome. Observe the encircling *sheath* of thickened bracts, and in front the *growing point.* Can you recognize the growing tips of young roots and branches? Note the difference.

(*c*) Study (*lp*) a cross section of the branch, and identify the three principal kinds of tissue. Note the arrangement of the fibro-vascular bundles, and the relative position of the phloëm and xylem. Sketch the section (*del.* 1′).

C.—FORM AND STRUCTURE OF THE FOLIAGE LEAF.

(*a*) Examine a leaf and observe its general outline. Note the form of its *base*, *apex*, and *margin*. Is the leaf *sessile*, or has it a *petiole?*

(*b*) Examine the leaf from its lower surface, and observe the plan and arrangement of its frame work (**venation**). Note its large *ribs* and their branches (**veins**), and the smaller branches (*m*) of the veins (**veinlets**). Has the leaf a prominent *midrib?*

(*c*) Do all the principal ribs run nearly parallel from the base to the apex (**parallel-veined**), or do they diverge at the base and send their branches in every direction (**netted-veined**), forming a network throughout the lamina or blade of the leaf? Sketch a leaf ($\times$ ½).

(*d*) Examine and compare the two surfaces of the leaf, and note in what respects they differ in appearance. Do you find trichomes (*m*)?

(*e*) Strip off a small piece of epidermis from the lower surface of the leaf, mount it in water, and examine it (*lp*). Study the epidermal cells, the stomata and their guard cells. Sketch a stoma, including the adjacent epidermal cells.

(*f*) Now strip off a piece of epidermis from the upper surface of the leaf, and study its cells. Sketch a small portion. What difference do you discover between the epidermis of the lower and upper surface?

(*g*) Make a transverse section of a portion of the leaf across one of the larger ribs. Mount it in water, and study

(*lp*) the fibro-vascular bundle. Toward which surface is the *phloëm* and toward which the *xylem?*

(*h*) Examine (*lp*) the structure of the lamina, and observe the epidermis of the upper and lower surfaces. Observe the parenchyma or tissue between the two epidermal layers (**mesophyll**).

(*i*) Study (*lp*) the mesophyll cells along the upper layer of the epidermis (**palisade cells**). Observe their shape and arrangement. Sketch a small region of palisade cells.

(*j*) Mount a small portion of a scale from the base of the aërial branch and examine it (*lp*). Is it parallel or netted-veined? Note the dark spots, and examine their contents. Crush one of them, and observe the needle-shaped crystals (**raphides**).

D.—THE FLOWER.

(*a*) Observe the general form and appearance of the flower. Note the several leaf-like parts arranged in different whorls or sets. Note the slender stem or *peduncle* which bears the flower. At what point on the branch is the peduncle attached to the branch?

(*b*) Observe the distal and somewhat enlarged end of the peduncle, *receptacle*, upon which are situated the parts of the flower.

(*c*) Observe the whorls of the leaf-like parts in the flower (**floral envelope** or **perianth**). Note the lower (outer) circle (**calyx**) and the upper (inner) circle of the floral envelopes (**corolla**).

(*d*) Note the number of separate parts (**sepals**) in the calyx. Note the number of parts (**petals**) in the corolla. How are the petals situated with reference to the sepals? Is a petal always found attached directly above the attachment of a sepal (**opposite**); or is its point of

attachment over the interval between the sepals (**alternate**)?

(*e*) Observe a whorl of sporophylls, the *stamens*, situated above the petals. Are they less or more leaf-like in appearance than the floral envelopes? Note the number of stamens. In how many circles are they arranged? Are the stamens opposite to or alternate with the petals?

(*f*) Observe a central column situated above the stamens (**pistil**), formed by several carpels more or less united. How many carpels evidently formed the pistil? What evidence have you?

(*g*) Make a sketch of the flower, representing all its circles of parts.

(*h*) Carefully examine one of the sepals and note its color, general outline, venation, and the form of its base and apex. Is the sepal sessile or petiolate? Sketch a sepal.

(*i*) Examine a petal and determine the same points. Sketch.

(*j*) Examine a stamen and observe its color and general form. Note the filament and its pollen-bearing sacs (**anther**). Sketch.

(*k*) Examine (*lp*) a cross section of the stamen through the anther and note the lateral pockets, the *pollen sacs*. Can you explain how the leaf or sporophyll has modified to form the pollen sacs?

(*l*) Identify in your section the *epidermis*, *parenchyma*, and *fibro-vascular bundles*. Sketch the section (*del.* 1′).

(*m*) Examine (*hp*) some pollen grains and note their color and shape. Note their surface markings. Sketch several pollen grains.

(*n*) Compare a stamen of Trillium with one of Scotch Pine

and name the points of resemblance and points of difference.

(*o*) Examine the pistil and observe its general form and appearance. Observe the lower enlarged portion, *ovary*, formed by the union of several carpels, and containing the ovules. Note its prominent ridges.

(*p*) Observe the portion of the carpel above the ovary (**style**) and at its distal end (*m*) its numerous spongy branches (**stigmas**). Sketch the pistil, showing ovary, style and stigma (× 2).

(*q*) Remove one of the styles, mount it in water and examine (*lp*). Observe the stigmas, and note the character of their surface. Do you find any pollen grains lodged on a stigma? Sketch a portion of a stigma showing the appearance of its surface.

(*r*) Examine a cross section of the ovary and observe its general appearance. Is it composed of one carpel (**simple ovary**), or of several carpels (**compound ovary**)? Can you identify the edges and middle portion of the carpels? How many cavities does the ovary contain (**one-celled, two-celled ovary, etc.**)?

(*s*) Observe the *ovules* and note the surfaces along which they are borne (**placentæ**). Are the placentæ situated along the wall of the cavity (**parietal placenta**) or in its central part (**central placenta**)?

(*t*) Observe the tissues in the carpels. How many fibro-vascular bundles do you find in each carpel? Make a careful sketch of the cross section of the ovary, representing all its parts (*del.* 1′).

(*u*) In terms of morphology which of the plant members does the stamen represent? Is it a leaf or some modification of a leaf (**phyllome**); a stem or some modifica-

tion of a stem (**caulome**) ; a plant hair or some modification of a plant hair, *trichome ;* a root or some modification of a *root?* What is the pistil? The rhizome? The rhizoid? The aërial branch? The pollen grains? The spores in the fern? The ovules?

OTHER WORK.

1. The life-history of Trillium.
2. Comparative review of the morphology of Trillium and Scotch Pine.
3. Trichomes and the origin of spores, pollen grains, and ovules.
4. Comparative review of the general morphology of the plant types studied.
5. Characteristics of the endogens and exogens.
6. Methods of pollination and the process of fertilization in Spermaphytes.
7. A synopsis of the characteristics of Angiospermæ and a list of the orders.

References. — 2 — 5 — 7 — 9 — 12 — 18 — 19 — 21 — 26 — 39 — 44 — 47 — 62 — 64 — 68 — 76 — 79 — 99 — 100 — 102 — 103 — 118 — 119 — 142.

STUDY IX.

A STUDY OF SEEDS AND SEEDLINGS.

COMMON BEAN (*Phaseolus vulgaris*).
INDIAN CORN (*Zea mays*).
SCOTCH PINE (*Pinus sylvestris*).

To show the germination of a monocotyledon, a dicotyledon and a polycotyledon.

Material Required.—(1) Ripe seeds of a Common Bean;* (2) mature fruit of the Indian Corn; (3) ripe seeds of the Scotch Pine.

Concerning the Material.

The seeds should be soaked in water at least ten hours before the external features and the embryos are studied. Those seeds from which seedlings are to be studied, should be sown in advance in order to have the seedling ready when this study is begun. The seeds may be sown in clean moist sand of four or five inches in depth and kept in a warm place. The tray or box containing the sand may be kept in a window, under the direct rays of the sun, provided the surface be protected by a moist cloth or paper until the seedlings appear. The common Buckwheat (**Fagopyrum esculentum**), on account of its rapid growth after germination, has some advantages over the Bean for this study, and the common Wheat (**Triticum vulgare**) is a good substitute for the Indian Corn. The Scotch Pine does not germinate as readily in this country as some other species of Pine. Seedlings of the Pine may usually be obtained from the gardeners.

*The large variety known as "butter bean" is desirable.

LABORATORY WORK.

MORPHOLOGY OF THE SEED AND SEEDLING.

A.—EXTERNAL MORPHOLOGY OF SEEDS.

(*a*) Examine a bean and note its size, shape and color. Observe the scar (**hilum**) on one edge, left by the seed-stalk (**funiculus**) to which the bean was attached in the "pod" or ovary.

(*b*) Near the hilum observe (*m*) a small opening (**micropyle**), and note its exact position. Observe the outer covering (**seed-coat**). With the point of your scalpel cut through the seed-coat and remove a small piece of it, and note its thickness.

(*c*) Study the external characters of a grain of Indian corn and observe the difference between its two sides. Can you find a *hilum*, *funiculus*, and *micropyle?* Examine its covering.

(*d*) Compare the external features of the bean and grain of corn with those of the seed of the Scotch Pine, and note the points of resemblance and points of difference. Sketch side by side these three seeds, faithfully representing all their external features (× 2).

B.—MORPHOLOGY OF THE EMBRYO.

(*a*) Remove the seed-coat from a soaked bean, by carefully cutting along the sides with the point of your scalpel. Observe the large thickened seed leaves (**cotyledons**), and note their appearance and position. How many are there?

(*b*) In the region of the hilum observe the young plant (**embryo**), and note its relation to the cotyledons. What do you suppose to be the function of the cotyledons? Carefully separate the cotyledons, allowing the embryo to retain its attachment to one of them.

(*c*) Study the embryo and observe its size, form, and color. Note the conical portion, the primitive stem (**caulicle**), and observe its relation to the cotyledons. Observe the flattened portion of the embryo (**plumule**), containing the first set of true foliage leaves, and the rudimentary stem above the first node or attachment of the cotyledons. Note the position of the plumule, in what direction does the caulicle extend with reference to the position of the micropyle?

(*d*) Remove the external covering of the grain of corn and examine it. This represents not only the seed-coat but also the wall of the ovary; hence a grain of the Maize is a ripened ovary with its contents (**fruit**, in the true or botanical sense).

(*e*) Examine (*lp*) a section of the fruit, taken longitudinally through the median plane of the embryo. Observe the two layers of the covering. Note the outer layer (**pericarp**), representing the wall of the ovary, and the inner or *seed-coat*. What is the botanical fruit of the Bean Plant? What important differences between the fruit of the Bean Plant and that of the Indian Corn?

(*f*) Observe the embryo and note its form and appearance. Where is it situated and how related to the remaining large yellow portion of the fruit (**endosperm**)? Observe the part of the embryo which is in contact with the endosperm (**scutellum**). Note the sheath of leaves or *apical* bud. Where is it situated? Have you found cotyledons in the grain of corn? Sketch the section representing endosperm, embryo, and scutellum.

(*g*) Examine a seed of Scotch Pine. Remove the seed-coat and note its character. Examine (*m*) the embryo and note the form, size, and general appearance. Identify endosperm, caulicle, and radicle. How many

cotyledons do you find? How are the cotyledons related to one another? Sketch side by side, the three embryos which you have now studied, and name all the parts represented in each sketch (*del.* 1½).

C.—MORPHOLOGY OF SEEDLINGS.

(*a*) Examine a seedling of the Bean and observe the stem, roots and cotyledons. Note the relative size of these parts and their general appearance.

(*b*) Study the roots. Do you find one principal or main root (**taproot**) which gives off other roots or branches; or do you find, instead of a taproot, many thread-like roots arising from about the same place (**multiple roots**)?

(*c*) Observe (*m*) the branches given off by the root. Remove a small portion of a branch, mount it in water and examine it (*lp*), and observe its tip. Sketch.

(*d*) Observe the young stem and note the distance below the cotyledons. How many nodes and internodes has the stem? Observe the relative length of the internodes.

(*e*) Examine the cotyledons and observe their form and color. Do you find any remains of the seed-covering in connection with the young plant?

(*f*) Study the first pair of foliage leaves, and note the *outline*, *base*, *apex*, *margin*, and *venation*. Are the leaves *parallel-veined* or *netted-veined?* How are the leaves arranged on the stem? Sketch a foliage leaf (*del.* 2′).

(*g*) Now examine a seedling of the Corn. Study the roots, stem, and leaves, as you did in the Bean, and make corresponding sketches.

(*h*) Compare the seedlings of the Bean and Corn with reference to their root, stems, form and venation of their leaves, and their leaf-arrangement or *phyllotaxy*.

(*i*) Name the points of difference between the seedlings of the Bean and Corn.

(*j*) Examine the seedling of the Scotch Pine or Austrian Pine and study it as you were directed to study the seedling of the Bean, and compare the Pine seedling with those of the Bean and Corn. Sketch, side by side, the three seedlings which you have now studied, observing their relative size.

OTHER WORK.

1. Comparative review of the seedlings studied in the laboratory.
2. The morphological significance and the physiology of germination.
3. Natural agencies in the dispersal of fruits and seeds.
4. Classification of the true or botanical fruits, with examples.
5. The nature and miscellaneous character of the "edible" fruits, with examples.
6. The nature, function and correlation of the members of the plant body, and the transformation of energy in the plant.
7. The distinguishing characteristics of a mineral or inorganic object.
8. The distinguishing characteristics of a plant.
9. The distinguishing characteristics of an animal.
10. The relation between the inorganic and organic kingdoms; between the animal and plant kingdoms.

References. — 12 — 18 — 19 — 29 — 32 — 40 — 43 — 55 — 57 — 59 — 61 — 65 — 69 — 75 — 90 — 93 — 96 — 97 — 111 — 113 — 132 — 139 — 143 — 166 — 168.

PART III.

CLASSIFICATION OF ANIMALS AND PLANTS.

NOTE.

It will be observed that each animal and plant selected as a Type in the Studies is chosen, in the following Synopses, as a representative of the Class to which it belongs.

A SYNOPSIS

OF THE

CLASSIFICATION OF ANIMALS.

This synopsis is a modification of the classification adopted by Dr. C. Claus. Although it is not the latest, it seems rather better adapted to the present purpose than later systems.

SYNOPSIS OF THE GROUPS.

A.—Protista—The lowest organisms, not distinctly animal or plant. Homogeneous structure. No nucleus known to be present.

B.—Protozoa—Unicellular animals, or simple colonies of similar organisms, each possessing one and frequently more than one, nucleus. Reproduction by fission or budding.

C.—Metazoa—Multicellular animals, consisting of a large number of cells which form a community or individual. Each individual is composed of a few or many kinds of cells, each kind performing a special function for the individual. Sexual reproduction.

SYNOPSIS OF THE BRANCHES.

GROUP B—PROTOZOA.

Branch I.

Protozoa—Characteristics of the group.

Class A.—Rhizopoda: *Amœba, Foraminifera, Heliozoa.*
Class B.—Infusoria: *Paramœcium, Vorticella.*
Class C.—Gregarinida: *Gregarina.*

GROUP C—METAZOA.

Branch II.

Porifera—A body composed of many cells capable of amœboid movements, more or less independent, and collectively supported by solid skeletal parts. There are internal canal systems and external pores.

Class A.—Spongia: *Spongilla, Grantia.*

Branch III.

Cœlenterata—Radially symmetrical animals. Body consists of two layers, ectoderm and endoderm. No true body cavity. A central cavity is present which serves both for digestion and circulation, and has only one external opening (mouth). The nervous system is entirely absent or but little specialized.

Class A.—Hydrozoa: *Hydra*, *Hydrozoa*, *Jellyfish*.
Class B.—Actinozoa: *Sea-anemone*, *Coral polyp*.
Class C.—Ctenophora: *Ctenophore*.

Branch IV.

Echinodermata—Animals with apparently radial symmetry, but really bilaterally symmetrical. An exoskeleton of calcareous spicules and plates. An alimentary canal with two external openings. A true body cavity. A true water-vascular system. A nervous system. A complicated metamorphosis.

Class A.—Crinoidea: *Sea-Lily*.
Class B.—Asteroidea: *Starfish*.
Class C.—Echinoidea: *Sea-Urchin*.
Class D.—Holothuroidea: *Sea-Cucumber*, *Synapta*.

Branch V.

Vermes—Bilateral animals with unsegmented or uniformly segmented bodies. Well marked anterior, posterior, dorsal and ventral regions of the body. No segmented lateral appendages. A dermal muscular system. Three germ-layers and usually no primitive stripe.

Class A.—Platyhelminthes: *Flat-worms*, *Tape-worm*.
Class B.—Nemathelminthes: *Round-worms*, *Trichina*.
Class C.—Annelida: *Earth-worm*, *Leech*.
Class D.—Rotatoria: *Rotifer*.

Branch VI.

Arthropoda—Bilaterally symmetrical animals, with bodies not uniformly segmented. Jointed segmented appendages. Body with a chitinous exoskeleton. Heart situated above the alimentary canal. Brain (supra-œsophageal ganglion) and segmented ventral nerve cord.

Class A.—Crustacea: *Crayfish*, *Cyclops*, *Barnacle*.
Class B.—Arachnida: *Spider*, *Scorpion*, *Mite*.
Class C.—Onycophora: *Peripatus*.
Class D.—Myriapoda: *Centipede*.
Class E.—Insecta: *Wasp*, *Beetle*, *Butterfly*, *Grasshopper*.

Branch VII.

Mollusca—Bilaterally symmetrical, unsegmented animals. Usually a calcareous univalve or bivalve shell. No locomotory skeleton. Heart with ventricle and two auricles. The central nervous system consists of the paired cerebral, visceral, pleural, and pedal ganglia.

Class A.—Lamellibranchiata: *Clam, Oyster, Pecten.*
Class B.—Scaphopoda: *Dentalium.*
Class C.—Gasteropoda: *Snail.*
Class D.—Pteropoda: *Pteropod.*
Class E.—Cephalopoda: *Squid, Cuttle-fish.*

Branch VIII.

Molluscoidea—Bilateral, unsegmented animals with crown of ciliated tentacles or spirally coiled buccal arms. Usually attached and enclosed by a cell or bivalve shell. One or more ganglia connected by a pharyngeal ring.

Class A.—Bryozoa: *Cristatella.*
Class B.—Brachiopoda: *Brachiopod.*

Branch IX.

Tunicata—Bilateral, sacular, or barrel-shaped animals with a gelatinous or cartilaginous mantle completely surrounding the body. Pharyngeal respiration and a distinct sacular heart. A simple nerve ganglion. Marine, fixed and free organisms.

Class A.—Tethyodea: *Ascidian.*
Class B.—Thaliacea: *Salpa, Doliolum.*

Branch X.

Vertebrata—Bilaterally symmetrical animals with internal skeleton; notochord or backbone; brain and dorsal nervous cord separated from body cavity; never more than two pairs of limbs.

Class A.—Pisces: *Amphioxus, Lamprey, Shark, Perch.*
Class B.—Amphibia: *Cœcilia, Salamander, Frog.*
Class C.—Reptilia: *Snake, Lizard, Turtle.*
Class D.—Aves: *Duck, Pigeon, Ostrich.*
Class E.—Mammalia: *Opossum, Cat, Man.*

A SYNOPSIS OF THE CLASSES OF VERTEBRATA.

Class A.

Pisces—Aquatic, cold-blooded vertebrates; exoskeleton of scales; permanent gills; median fins and paired pectoral and pelvic fins; heart consisting of an auricle and ventricle.

Order I.—Leptocardii: *Amphioxus.*
Order II.—Marsipobranchii: *Petromyzon, Lampreys.*
Order III.—Selachii: *Shark, Skate, Ray.*
Order IV.—Ganoidei: *Sturgeon, Gar-Pike.*
Order V.—Teleostei: *Perch, Cod, Eel.*
Order VI.—Dipnoi: *Ceratodus, Protopterus.*

Class B.

Amphibia—Cold-blooded vertebrates; usually no exoskeleton; two occipital condyles; heart consisting of three cavities; pulmonary and branchial respiration. Development with metamorphosis.

Order I.—Apoda: *Cæcilia.*
Order II.—Caudata: *Necturus, Newt, Salamander.*
Order III.—Batrachia: *Toad, Frog.*

Class C.

Reptilia—Cold-blooded vertebrates with exoskeleton of scales or bony plates; one occipital condyle; heart with three, or indistinctly four cavities, exclusively pulmonary respiration, embryo with ammion and allontois.

Order I.—Ophidia: *Snake.*
Order II.—Lacertilia: *Lizard.*
Order III.—Chelonia: *Turtle, Tortoise.*
Order IV.—Crocodilia: *Crocodile, Alligator.*

Class D.

Aves—Warm-blooded, oviparous vertebrates with exoskeleton of feathers; one occipital condyle; heart with four complete cavities; right aortic arch persists; anterior limbs organized for flight, posterior for locomotion on land or water; three eyelids; pulmonary respiration.

Order I.—Natatores (Swimming birds): *Swan, Gull.*
Order II.—Grallatores (Waders): *Plover, Snipe.*
Order III.—Gallinacei (Fowls): *Quail, Peacock.*
Order IV.—Columbinæ (Pigeons): *Dove, Pigeon.*
Order V.—Scansores (Climbers): *Woodpecker, Parrot.*
Order VI.—Passeres (Passarines): *Sparrow, Swallow, Lark.*
Order VII.—Raptatores (Birds of prey): *Owl, Buzzard, Eagle.*
Order VIII.—Cursores (Runners): *Ostrich, Cassowary.*

Class E.

Mammalia—Warm-blooded viviparous* vertebrates with exoskeleton of hairs; double occipital condyle; heart with four chambers; red blood corpuscles double concave; complete diaphragm; pulmonic respiration; suckle their young.

Order I.—Monotremata: *Ornithorhynchus.*
Order II.—Marsupialia: *Kangaroo, Opossum.*
Order III.—Edentata: *Armadillo, Sloth.*
Order IV.—Cetacea: *Whale, Manatee.*
Order V.—Perissodactyla: *Horse, Rhinocero.*
Order VI.—Artiodactyla: *Pig, Deer, Buffalo.*
Order VII.—Proboscidia: *Elephant, Mastodon.*
Order VIII.—Rodentia: *Mouse, Beaver, Rabbit.*
Order IX.—Insectivora: *Hedgehog, Mole.*
Order X.—Pinnipedia: *Seal, Walrus.*
Order XI.—Carnivora: *Cat, Dog, Wolf.*
Order XII.—Chiroptera: *Bat.*
Order XIII.—Prosimiæ: *Lemurs.*
Order XIV.—Primates: *Ape, Man.*

*The Monotremes lay eggs; hence oviparous.

A SYNOPSIS

OF THE

CLASSIFICATION OF PLANTS.

This synopsis is intended for reference in connection with the study of the Plant Types. It gives, in a general way, the characteristics of the Groups and Branches of the Cryptogams, and more fully of the Orders of the Flowering Plants. It will give the student a general notion of the natural relationship of plants and an understanding of the scheme of systematic classification. An attempt is made in the arrangement to co-ordinate the Groups, Branches, and Orders in accordance with the latest views of some of our best authorities. The classification here adopted is, with some modification, that given by Professor Bessey in his text-books on Botany.

SYNOPSIS OF THE GROUPS.

A.—Thallophytes—*Plants with no distinction of stem and leaves*, Plant body usually a thallus, and small.

B.—Bryophytes (Moss-worts)—*Plants usually with distinction of stem and leaves, but with no woody system.* Always chlorophyll-bearing. Leaves never bearing spores.

C.—Pteridophytes (Fern-worts)—*Plants with a woody stem, but not producing seeds.* Flowerless plants with leaves bearing spores.

D.—Spermaphytes (Seed-plants)—*Plants which produce seeds.* Flowering plants with highly complex systems of tissue.

SYNOPSIS OF THE BRANCHES.

GROUP A—THALLOPHYTES.

Plant body usually a thallus or small, but sometimes large. *No true stem, leaf, or root.*

Branch I.

Protophyta—(The Sexless Plants). The lowest, simplest, and most minute plants. Chiefly aquatic. Unicellular or cells in loosely united masses. No sexual cells known. *Reproduction by fission and endo-spores.*

Class A.—Myxomycetes (Slime-moulds).*

Class B.—Schizomycetes (Bacteria and Yeast-plants).

Class C.—Cyanophyceæ (Green Slimes).

* NOTE. — The Myxomycetes are regarded by good authorities as belonging more properly to the animal forms of life.

Branch II.

Zygophyta—(The Unisexual Plants). Plants extremely variable in size and complexity of structure. Aquatic and chlorophyll-bearing, or saprophytic. *Sexual reproduction present. Very little if any difference in form, size, color and origin of the male and the female cells.*

Class A.—Zoösporeæ.

Class B.—Conjugateæ (Yoke-weeds).

Branch III.

Oöphyta —(The Egg-spore Plants). Plant-body variable in size and general appearance. Aquatic and chlorophyll-bearing. Saprophytic and parasitic. A considerable difference between the male (antheridium) and the female (oögonium) sexual cell in size and appearance.

Class A.—Zoösporeæ. (Valvox.)

Class B.—Œdogonieæ.

Class C.—Cœloblasteæ (Green Felts, Water-moulds, Mildews and White rusts).

Class D.—Fucaceæ (Rock-weeds).

Branch IV.

Carpophyta—(The Spore-fruit Plants). *Plant-body a thallus, well developed* excepting in the parasitic and saprophytic forms. *A spore-fruit which is the result of fertilization.*

Class A.—Coleochætæ.

Class B.—Florideæ (Red seaweeds).

Class C.—Ascomycetes (Sac-fungi).

Class D.—Basidiomycetes (Puff-balls and Toad-stools).

Class E.—Characeæ (Stone-worts).

GROUP B—BRYOPHYTES.

Branch V.

Bryophyta—(Characters of the Group.)

Class A.—Hepaticæ (Liver-worts).

Class B.—Musci (Mosses).

GROUP C—PTERIDOPHYTES.

Branch VI.

Pteridophyta.—(Characters of the Group.)

Class A.—Filicinæ (Ferns).

Class B.—Equisetinæ (Horntails).

Class C.—Lycopodinæ (Lycopods).

GROUP D—SPERMATOPHYTES.

Branch VII.

Spermaphyta—(Characters of the Groups.

Class A.—Gymnospermæ (Gymnosperms). Seeds not enclosed in an ovary, but naked upon a carpellary in the form of a scale, bract, or disc.

Fruit a cone or berry.
Order I.—Cycadaceæ (Cycads).
Order II.—Coniferæ (Conifers).
Order III.—Gnetaceæ (Joint-Firs).

Class B.—Angiospermæ (Angiosperms). Seeds enclosed in an ovary formed by carpellaries.

ARTIFICIAL KEY.

The aim of this Key is to give the student an introduction to the practical use of an "Artificial Key" in identifying plants. It is not complete in the sense of including every known wild plant of a given locality, but for the object in view, it is believed, will serve much better than the complete Manuals of Botany. The Key is made as simple as possible, consistent with accuracy, and embraces sixteen Orders, twenty-eight of the most important Families, fifty common Genera, and sixty-eight representative Species. These are among the most common plants and found generally throughout the United States.

The instructor, by glancing along the right-hand margin, can readily observe what plants are included in the Key and can see to it that such plants are provided for practical study and identification. The Glossary is an absolute necessity and the student should be required to make constant reference to it as long as he has the least doubt concerning the meaning of a term. In the following Key the names of Families appear in **full-face,** those of genera in *Italics*, and those of species in Roman type.

CLASS B.—ANGIOSPERMÆ. SYNOPSIS AND KEY TO THE ORDERS.

DIVISION A—MONOCOTYLEDONS.

Stem never with woody bundles arranged in concentric layers, but scattered without any definite order; leaves usually parallel-veined; parts of the flower usually in threes, never in fives; embryo with one cotyledon.

A. Ovary Superior.

(a) Flowers with the ordinary envelopes, usually regular.

Order I.

Alismales. (3 fam.)—*Water Plantain, etc.—Parts of the flower all distinct.* Perianth, 2 or 3-parted or more; stamens, 1-indefinite; ovaries usually several or many, 1-celled, 1-ovuled; *herbaceous water plants;* occasionally delicate and nearly colorless herbs of the tropics.

Order II.

Liliales. (8 fam.) —*Lily, Spider-wort, etc.*—Perianth, 3-parted; glumaceous, partly or *usually entirely petaloid*, rarely *irregular;* stamens 3–6; styles 1–3; ovary becoming a 1- *usually 3-celled* capsule or berry. Plant often bulbous, with *usually narrow leaves.* (p. 181.)

(b) Flowers usually spadaceous.

Order III.

Aroidales. (5 fam.) —*Arum, etc.*—Inflorescence a spadix, usually enveloped *in a spathe.* Perianth never petaloid, usually abortive or inconspicuous. Flowers often unisexual; fruit superior; leaves and *plants usually large*, but small and *floating* in one family. (p. 182.)

Order IV.

Palmales. (3 fam.) —*Palm, etc.*—Inflorescence a spadix. Perianth as in Order III. *Fruit large or very large;* laminæ broad-branched, pinnate or flabelliform; trees or shrubs.

(c) Flowers glumaceous.

Order V.

Glumales. (5 fam.) —*Grass, Sedge, etc.*—Flowers glumaceous and in the axils of *scales* which are *arranged in spikelets*, or occasionally with an inconspicuous 3-parted perianth; *stamens* 1–6, *usually 1–3; ovary 1–3 celled*, and *1–3-seeded. Grass-like plants.*

B. Ovary Inferior.

(a) Flowers usually regular.

Order VI.

Hydrales. (1 fam.) —*Frog's Bit.*—Perianth 6-parted; regular stamens 3–12; *ovaries inferior, 3 or more, and 1-seeded;* unisexual or polygamous; small water plants.

Order VII.

Iridales. (7 fam.) —*Amaryllis, Iris, etc.*—Perianth occasionally irregular, 3 or 6-parted, *usually petaloid;* stamens 3 or 6, in one family only 1–5 pollen bearing; styles *1–3*; fruit variable, 3-celled in northern plants. Plants often with *equitant* leaves, occasionally *climbing* and with *ribbed* and *netted-veined, petioled* leaves. (p. 182.)

(b) Flowers very irregular.

Order VIII.

Orchidales. (2 fam.) —*Orchis, Lady Slipper.*—Perianth 6-parted, *very irregular;* fertile stamens 1 or 2, more or less united with the style into a common column; *ovary inferior, twisted and 1-celled with many small seeds.* (p. 183.)

DIVISION B—DICOTYLEDONS.

Stem with distinct bark, wood, and pith which are concentrically arranged; netted-veined leaves; parts of the flower commonly in fives or fours, seldom in threes; embryo with a pair of cotyledons or several (Pines) cotyledons.

A. Flowers Choripetalous.

(*a*) *Stamens usually more numerous than the petals, inserted on the receptacle.*

(*1*) *Herbs; stamens 12-indefinite.*

Order IX.

Ranales. (8 fam.) —*Crowfoot, Barberry, Water Lily, etc.*—*Usually bisexual.* Perianth with both calyx and corolla, rarely *apetalous;* parts of the flower arranged spirally or in whorls which are usually dimerous or trimerous; stamens rarely definite; ovaries 1-many, separate; seeds 1-many. (p. 183.)

(2) *Aromatic shrubs or trees.*

Order X.

Laurales. (3 fam.) —*Laurel, etc.*—Flowers mostly unisexual; apetalous; stamens free or monodelphous; *ovary superior, 1-celled, 1-seeded.* Aromatic herbs, shrubs or trees.

(3) *Herbs; stamens usually 5 or 6.*

Order XI.

Parietales. (10 fam.) —*Mustard, Violet, Poppy, etc.*—Flowers bisexual; perianth with both calyx and corolla; regular or irregular; stamens definite or indefinite; ovary *usually 1-celled, with parietal placentæ.* (p. 183.)

(4) *Shrub or trees, except frequently in Order XII. Flowers usually unisexual, sometimes perfect. Generally apetalous.*

Order XII.

Urticales. (7 fam.)—Including *Malvales. Nettle, Mallow, Linden, etc.*—Perianth commonly *present* 3-9-parted, and calyx-like, occasionally with both *calyx* and corolla; stamens few to indefinite, often in the *corolla bearing families, united into a column;* ovary superior, 1-many-celled. Bark often mucilaginous or *very tough.* (p. 184.)

(5) *Herbs or shrubs. Flowers very minute, usually perfect.*

Order XIII.

Piperales. (3 fam.) —*Pepper, etc.* Flowers perfect or unisexual and in spikes; stamens 6-20; *ovary superior, and 1-celled and 1-seeded; mostly herbs; some aquatic; often pugnent.*

(6) *Herbs. Flowers usually unisexual, occasionally perfect, rarely with corolla. Juice milky.*

Order XIV.

Euphorbiales. (10 fam.)—*Spurge, etc.*—Flowers mostly unisexual; sepals present or absent; stamens variable in number; *ovary 2-many-celled, superior;* plants usually with milky juice. Occasionally shrubs or trees.

(7) *Herbs without previous characters. Flowers often apetalous, generally perfect.*

Order XV.

Caryophyllales.—*Pink, Goose-foot, Buck-wheat, etc.*—Calyx *usually present* (7 fam.) corolla *occasionally;* stamens usually *of a different number from sepals;* ovary superior, *1-celled*, seeds 1 or more, *basal or borne on a central placenta*, occasionally *several celled*, with *axial placenta*. Occasionally shrubs.

(*b*) *Stamens commonly on a disc; variable in number, often only a few, never many except rarely in Order XVI.*

(1) *Herbs; stamens 10.*

Order XVI.

Geraniales.—*Geranium, Rue, Flax, etc.*—Flowers often irregular, 4 or 5-parted; (11 fam.) stamens often twice the number of petals; *ovary superior*, entire, lobed, or of nearly separate carpels. Herbs, shrubs, or trees, often *strong scented*. (p. 184.)

(2) *Climbing shrubs; stamens 5.*

Order XVII.

Celastrales.—*Vine, Staff-tree, etc.*—Flowers regular, perfect; stamens usually (4 fam.) the same in number as the petals, alternate or opposite to them; ovary superior, entire; usually shrubs or trees, often climbing, generally with simple leaves. (p. 184.)

(3) *Shrubs or trees; stamens variable.*

Order XVIII.

Sapindales.—Including *Amentales and Quernales.—Maple, Walnut, Oak, etc.* (12 fam.) Perianth *often absent or represented by scales, occasionally present;* inflorescence *commonly contracted, most commonly* one or both kinds of flowers in *aments;* stamens *very variable* in number (3-20); ovary 1-several celled, *usually superior;* fruit *often a nut*. (p. 185.)

Order XIX.

Santalales.—*Sandal-wood, etc.*—Ovary inferior; shrubs or trees, rarely herbs, (3 fam.) mostly parasitic.

Order XX.

Olacales.—*Holly, etc.*—Flowers regular, Stamens as in Order XVIII; ovary (3 fam.) superior, entire, 1-many celled; shrubs and trees, *often evergreen*. Usually tropical. Sepals rarely distinct, petals and stamens usually on the calyx.

(*c*) *Stamens variable, usually equal to the number of petals, occasionally more numerous, usually on the calyx.*

(1) *Flowers 4-parted; stamens usually 8.*

Order XXI.

Myrtales. (6 fam.) —*Myrtle, Evening Primrose, etc.*—Flowers tetramerous, regular; stamens twice as many as petals, or in two whorls, or by branching, very numerous; ovary usually inferior, syncarpous; placenta axial; leaves simple and usually entire.

(2) *Flowers, 3-parted, apetalous. Herbs.*

Order XXII.

Asarales. (2 fam.) —*Birthwort, etc.*—Flowers apetalous, mostly 3-parted; stamens definite, ovary inferior, usually 6-celled and many-seeded. Herbs. (p. 185.)

(3) *Flowers usually 4-parted, apetalous shrubs or trees.*

Order XXIII.

Daphnales. (4 fam.) —*Mazereum, etc.*—Usually apetalous, flowers perfect; tetramerous; calyx petaloid; stamens in one or two whorls; ovary superior, 1-celled, with a *single seed; trees or shrubs.*

(4) *Flowers 5-parted, not in umbels, in some families irregular.*

Order XXIV.

Rosales. (8 fam.) —*Rose, Pulse, Saxifrage, etc.*—Flowers mostly regular, occasionally irregular; pentamerous, occasionally tetramerous; stamens 5–30, often united; carpels one or more, *usually free in bud*, sometimes *united afterwards with calyx-tube* or enclosed in the swollen top of the peduncle; styles usually distinct; fruit variable, in one large family (Leguminosæ) a legume; leaves, often compound. Herbs, shrubs, or trees. (p. 185.)

(5) *Flowers small, 5 or 4-parted, in umbels or corymbs; stamens 4 or 5.*

Order XXV.

Umbelalles. (3 fam.) —*Parsnip, Dog-wood, etc.*—Perianth 4 or 4-parted; *stamens as many as petals and alternate with them;* a nectiferous disc between stamens and style; ovary inferior, 1-many-celled; flowers in *umbels* or *corymbs.*

(6) *Flowers usually many-parted.*

Order XXVI.

Ficodales. (2 fam.) —*Cactus, etc.*—Perianth usually many-parted; sepals and petals often alike; petals sometimes wanting; stamens usually *many;* ovary mostly inferior, 1-many-celled; mostly fleshy herbs, often stemless.

7) *Flowers usually large; ovary usually inferior.*

Order XXVII.

Passiflorales. (7 fam.) —*Passion Flower, Gourd, Begonia, etc.*—Flowers usually regular; stamens variable, often united; ovary usually inferior, syncarpous, 1-several-celled, with parietal placentæ; herbs, shrubs or trees, often *trailing* or *climbing.*

B. Flowers Gamopetalous.

(*a*) *Corolla regular; leaves usually alternate excepting Phlox.*

(1) Shrubs or shrubby plants; stamens usually twice as many as petals. *Seeds many.*

Order XXVIII.

Ericales. (3 fam.) —*Heath, etc.*—Flowers regular; stamens as many or twice as many as the petals, free from the corolla; ovary superior, 2-many-celled, style one. (p. 186.)

(2) Herbs; stamens as many as petals and opposite to them.

Order XXIX.

Primulales. (4 fam.)—Flowers mostly regular; pentamerous; stamens usually 5, opposite; ovary superior, 1-celled (2-celled in Plantaginaceæ); leaves *alternate*, often *radical*. (p. 186.)

(3) *Shrubs or trees; stamens usually alternate with petals. Seeds few.*

Order XXX.

Ebenales. (3 fam.) —*Ebony, etc.*—Flowers regular; 4-8-parted; stamens twice as many as petals, or more numerous, usually alternate with the petals; ovary superior; 2-many-celled; seeds usually *solitary in the cells; shrubs or trees with alternate leaves.*

(4) *Herbs; flowers 5-parted; stamens 5, alternate with the petals; leaves usually alternate, occasionally opposite.*

Order XXXI.

Polemoniales. (5 fam.)—*Phlox, Borrage, Night-shade, etc.*—Flowers regular, pentamerous; stamens 5, alternate with petals; ovary superior, 2-several; celled; leaves usually alternate. (p. 186.)

(*b*) *Corolla usually irregular and more or less 2-lipped.*

(1) *Ovary 2 or 4-celled and seeds solitary.*

Order XXXII.

Lamiales. (3 fam.) —*Mint, Verbena, etc.*—Flowers *irregular, usually* bilabiate; stamens usually 2 or 4; ovary superior with solitary seeds in the 2-4 cells; plants *with square stems* and *opposite leaves*, often *aromatic.*

(2) *Ovary 2-celled, seeds never solitary.*

Order XXXIII.

Personales. (8 fam.)—*Fig-wort, etc.*—Flowers irregular, usually bilabiate, stamen 4 or 5; ovary superior, *with many seeds in the cells; leaves various, not aromatic.*

(*c*) *Corolla regular; leaves opposite.*

Order XXXIV.

Gentianales. (6 fam.)—*Gentian, Milk-weed, Olive, etc.*—Flowers regular; stamens usually as many as petals and alternate with them; ovary superior; leaves opposite.

(*d*) *Flowers regular or irregular; milky juiced plants.*

Order XXXV.

Campanales.—Flowers usually irregular; stamens usually 5, sometimes less, often (3 fam.) united by their anthers, free from corolla; ovary inferior, 1-to 6-celled, with many seeds in each cell.

(*e*) *Flowers aggregated, juice not milky.*

Order XXXVI.

Rubiales. —*Madder, Honey-suckle, etc.*—Flowers regular or irregular; stamens (2 fam.) on the corolla and isomerous with its lobes; ovary inferior; 2-to many-celled, each cell with 1 to many ovules; calyx never pappose.

(*f*) *Flowers many on a common receptacle.*

Order XXXVII.

Asterales. —*Composite, etc.*—Flowers regular or irregular; stamens on the (4 fam.) corolla, isomerous with its lobes; ovary inferior; 1-celled, 1-ovuled (rarely 2- to 3-celled); calyx often greatly reduced, forming a pappus or wanting. (p. 187.)

KEY TO THE FAMILIES, GENERA AND SPECIES.

MONOCOTYLEDONS.

Order II.

Liliales. —**A.** Flowers *regular, 6-androus;* perianth usually *corolla-like;* fruit 3-celled, a capsule or berry. **Liliaceæ**

a *Climbing shrubs* or shrubby plants; flowers unisexual; *leaves broad.* *Smilax*

(*a*) Almost herbaceous, not thorny; flowers greenish, very offensive. *S.* herbacea

b *Herbs.*

(*a*) *Flower bracts scarious;* flowers umbellate, scapose: leaves narrow, from a coated bulb; strong scented plants. *Allium*

(1) Leaves keeled, linear; flowers pink, without bulblets intermixed. *A.* cernuum

(2) Leaves flat, linear; bulblets mixed with the flowers. *A.* canadense

(*b*) *Flowers bracts scarious;* parts of perianth *united,* cylindrical; flowers *few, axillary,* white or greenish; stem leafy, from a rootstock. *Polygonatum*

(1) Flowers 2-8; plant large, glaucous. *P.* giganteum

(2) Flowers 2, plant small. *P.* biflorum

(*c*) *Flowers bracts scarious;* parts of perianth *distinct;* flow-

ers *small, white, racemose;* stem leafy, from a rootstock. *Smilacina*

(1) Flowers in a *racemose panicle.* *S.* racemosa

(2) Racemes simple, leaves 3-12. *S.* stellata

(3) Racemes small, leaves 1 or 2, broad, *S.* bifolia

(*d*) *Flower bracts wanting, or greenish;* fruit a *capsule;* scape from a solid bulb, with a *pair of leaves* at base. *Erythronium*

(1) Flowers nodding, pink-white. *E.* albidium

(*e*) *Flower bracts wanting, or greenish;* fruit a *berry;* stem from a rootstock, bearing 3 leaves in a terminal whorl; flower 1, large. *Trillium*

(1) *Ovary 6-angled;* flowers *sessile, purple,* sepals reflexed. *T.* recurvatum

(2) *Ovary 6-angled,* winged; *flowers on long, usually declined peduncles,* white or purplish; stigmas *stout, recurved* or spreading. *T.* erectum

B. Flowers regular, or irregular, with three green sepals and 3 *fugacious,* colored petals; stamens 6; fruit a pod; sap very mucilaginous. **Commelinaceæ**

a Flowers regular; petals blue, showy; leaves narrow. *Tradescantia* virginica

Order III.

Aroidales. —A. Flowers perfect, or monœcious upon the same spadix, occasionally dicœcious; with 4-6 scale-like sepals or none. **Aroideæ**

a Flowers *naked,* born *on the base* of the spadix, which is surrounded by a spathe. *Arisæma*

(*a*) Leaves usually 2, 3-parted. *A.* triphyllum

(*b*) Leaves usually 1, 7-11-parted. *A.* dracontium

b Flowers with a calyx, covering the globular spadix; stemless, with purple spathe; very early. *Symplocarpus* fœtidus

Order VII.

Iridales. —A. Perianth corolla-like; stamens 6, anthers introrse; often bulbous rooted and scapose. **Amaryllidaceæ**

a Leaves *grass-like;* stem scapose from a *solid bulb;* flowers 1-several, *yellow.* *Hypoxis* erecta

B. Perianth corolla-like; from *a spathe; stamens 3, anthers extrorse; root not bulbous;* leaves often *equitant.* **Iridaceæ**

a *Stigmas opposite to the anthers:* leaves sword-shaped; styles *petaloid.* *Iris*

(*a*) Flowers blue; plant large. *I.* versicolor

b Stigmas *alternate with the anthers;* stamens *monodelphous; grass-like* plants. *Sisyrinchium*

(*a*) Flowers blue or whitish, opening in the sunshine, spathe *solitary.* *S.* augustifolium

Order VIII.

Orchidales. —A. Terrestrial, *with very irregular flowers;* stamens and style connate; *anthers 1, 2 or 3.* **Orchidaceæ**

a Flowers small in spiral racemes. *Spiranthes*

b Flowers large, pink, few on a leafy bracted scape; leaves 2 large, not fleshy. *Orchis* spectabilis

c Flowers large, moccasin-like, 1–3 in number. *Cypripedium*

(*a*) Flowers yellow, lip 1′ or more long. *C.* pubescens

(*b*) Flowers pink, very large; stem leafy. *C.* spectabile

(*c*) Flowers smaller, white. *C.* candidum

DICOTYLEDONS.

Order IX.

Ranales. —A. Flowers *usually 5-parted*, sometimes apetalous; *stamens and carpels usually many and distinct;* the fruit an akene, follicle or berry. **Ranunculaceæ**

a Petals *none;* leaves radical, 3-lobed, the lobes acute, flowers pink to blue, very early. *Hepatica* acutiloba.

b Petals *present.*

(*a*) 5, spurred, reddish. *Aquilegia* Canadensis

(*b*) 5, without spurs, yellow, with a scale at the base of each. *Ranunculus*

(1) Low; flowers large, 1′, early; leaves divided, root *fascicled.* *R.* fascicularis

(2) Tall, 1°; flowers very small; leaves round, heart-shaped or kidney-shaped. *R.* abortivus

B. Sepals and *petals in 2 or 3 rows of 3;* stamens *opposite* the petals; carpel 1. **Berberidaceæ**

a Sepals 6; petals 6-9; stamens 12-18; flowers large, white; leaves large. *Podophyllum* peltatum

C. *Aquatics; sepals 4-6*, petals *many*, stamens *indefinite;* flowers large and showy; leaves often peltate, large. **Nymphaceæ**

a Sepals 4; ovary 12-35 celled; flowers *white*, greenish outside nearly scentless. *Castalia* tuberosa

Order XI.

Parietales. —A. *Flowers 4-parted; stamens 6; pod 2-celled* long or short. **Cruciferæ**

a Pod *short, obcordate*, wingless, many-seeded, flowers small, white. *Capsella* bursa-pastoris

b Pod long, flat, linear; flowers *large, white* or *purplish; stems leafy*, leaves simple, dentate. *Cardamine* rhomboidea

c Pod long, linear, beaked or pointed; flowers yellow. *Brassica* sp.

B. Flowers *5-parted, irregular*, lower *petal spurred;* anthers 5, connate; pod 1-celled, 3-valved; several seeded. **Violaceæ**, *Viola*

a Stemless, flowers blue.
(*a*) Lateral petals bearded; leaves cordate or reniform. *V.* cucullata
(*b*) Lateral petals, beardless; flowers large, pale; leaves pedate. *V.* pedata
b Leafy stemmed.
(*a*) Flowers yellow, veined. *V.* pubescens

Order XII.

Urticales. —**A.** Trees with alternate, *simple pinnate veined* leaves. Fruit a *winged samara*. Flowers crowded, small, in spring. **Ulmaceæ**, *Ulmus*
a Inner bark very mucilaginous. *U.* fulva
B. *Trees*, with large thin leaves; *Fruit* a *globular nut*. Flowers with *sepals* and *petals*, 5-parted, stamens many: mucilaginous. **Tiliaceæ**
a Leaves *green, glabrous;* flowers cream-colored, very fragrant, with peduncle united to a bract. *Tilia* americana
C *Herbs*, flowers *usually 5-parted*, complete; stamens *many in a column*. **Malvaceæ**
a Stamen column anther bearing at the top; stigmas on inner face of styles; involucel of 3 bractlets. *Malva*
(*a*) Creeping, flowers small, pink. *M.* rotundifolia

Order XVI.

Geraniales. —**A.** Flowers regular or irregular usually *5-parted;* ovary *3-5-lobed;* mostly herbs with alternate leaves; often strong scented **Geraniaceæ**
a Flowers 5-parted; 5 glands alternating with the petals, style 5 cleft; stamens 10. *Geranium*
(*a*) Rootstock *perennial;* leaves large 5-7 parted, flowers *large, showy, pink*. *G.* maculatum
b Flowers 5-parted; no glands; leaves 3-foliate; juice sour. *Oxalis*
(*a*) Flowers pink. *O.* violacea
(*b*) Flowers yellow. *O.* stricta

Order XVII.

Celastrales.—**A.** Climbing shrubs, with *tendrils opposite the alternate leaves; flowers small, crowded*. **Ampelidæ**
a Leaves simple, palmate-veined. *Vitis*
b Leaves digitately 5-foliate; tendrils dilated at the tips. *Ampelopsis* quinquefolia
B. *Twining* shrub with simple, alternate leaves, and small 5-parted greenish flowers in racemes; fruit orange, red within. *Celastrus* scandens

Order XVIII.

Sapindales.—A. Trees with *alternate pinnately compound* leaves; sterile flowers in *aments: fruit a nut.* **Juglandaceæ**

a Sterile flowers in simple catkins. *Juglans*

(*a*) Petioles, branches and *fruit clammy.* *J.* cinerea

(*b*) Petioles, branches and *fruit not clammy.* *J.* nigra

b Sterile flowers in clustered catkins. *Hicoria*

a. leaflets 5. bark in plates, rough. *H. ovata*

B. Shrubs or trees with *alternate simple* leaves; fruit usually a nut. **Cupuliferæ**

a Sterile flowers in slender catkins, with a calyx, fruit a rounded nut, borne in a cup-like scaly involucre. *Quercus*

(*a*) Cup with mossy fringe, acorn large. *Q.* macrocarpa

C. Trees or shrubs, with *opposite*, *simple*, *palmate* veined leaves (in our examples); flowers crowded or cymose or corymbose. **Sapindaceæ**

a Trees with winged fruit, simple leaves. *Acer*

(*a*) Leaves *silvery beneath;* flowers red in clusters in early spring. *A.* dasycarpum

(*b*) Leaves *green beneath;* flowers pale yellow, corymbed, later. *A.* saccharinum

Order XXII.

Asarales. —A. Flowers *apetalous*, 3-parted; stamens 6-12; ovary 6-celled, many-seeded. **Aristolochiaceæ**

a Stemless, with 1 or 2 leaves; stamens 12, *Asarum*

(*a*) Leaves reniform, velvety; flowers dull purple, the lobes abruptly spreading, pointed. *A.* canadense

Order XXIV.

Rosales. —A. Flowers regular, 5-parted; stamens usually numerous on the calyx, pistils 1-many, distinct or united with the calyx-tube; leaves usually alternate. **Rosaceæ**

a Ovary superior.

(*a*) Calyx *deciduous; pistil 1;* fruit a drupe. *Prunus*

(1) Flowers white, *racemose;* small tree, *thornless*, with large oval leaves and astringent fruit. *P.* virginiana

(2) Flowers white, *umbellate;* small tree, *thorny*, with oval leaves, *after the flowers.* *P.* Americana

(*b*) Calyx *persistent, with bractlets;* pistils many, heaped in a head; flowers white; fruit pulpy. Fragaria

(1) Leaves firm, silky-hairy beneath. *F.* virginiana

b *Ovaries superior, but enclosed in fleshy calyx tube; flowers large* and showy; *often thorny.* *Rosa*

(*a*) *Styles distinct;* sepals *spreading after flowering*, and deciduous; leaflets 5-7, *coarsely toothed;* stipules *narrow;* spines slender, straight, low, 1-3° *R.* Humilis

c Ovary inferior.

(*a*) *Thorny tree* with ovate, irregularly toothed leaves, and large pink flowers in small corymbose clusters. Pistils 2-5. *Pirus* coronaria

B. Flowers usually irregular, 5-parted; stamens usually 10; carpel 1 becoming a legume. **Leguminosæ**

a Stamens *10, distinct;* pod *inflated;* leaves usually 3-foliate; herbs. Baptisia

(*a*) Flowers small, yellow; plant smooth. *B.* tinctoria

(*b*) Flowers large, cream-colored; plant *low*, soft, hairy. *B.* leucophoea

(*c*) Flowers large, white; plant tall, stout, glaucous. *B.* leucantha

C. Stamens 10, *Monodelphous;* leaves digitate, many-foliate; flowers pale purple, in a raceme, showy. *Lupinus* perennis

c Stamens 10, *diadelphous.*

(*a*) *Herb, creeping;* leaves 3-foliate; flowers small, white, in a head. *Trifolium* repens

(*b*) *Tree, thorny;* leaves odd-pinnate; flowers in raceme white, sweet scented, showy. *Robinia* pseud-acacia

Order XXVIII.

Ericales. —A. *Shrubs or shrubby;* flowers regular, 4-5-parted; stamens usually twice the *number of petals and free from* them; ovary superior. **Ericaceæ**

Order XXIX.

Primulales.—A. *Herbs*, flowers *5-parted*, stamens as many *as the petals and opposite to them.* Style 1. **Primulaceæ**

a *Ovary superior;* anthers *conniving in a cone;* perianth *reflexed*, petals pink or white, showy, flowers *in umbels* on a *naked scape.* *Dodecatheon* meadia

Order XXXI.

Polemoniales.—A. Flowers regular 5-parted, petals *convolute* in bud; ovary 3-celled with 1-many seeds in each cell, axial; style 3-cleft. **Polemoniaceæ**

a Corolla *salver-shaped;* leaves opposite. *Phlox*

(*a*) Flowers *corymbed.*

(1) Petals *pink, entire;* leaves narrow, tapering to a sharp point; hairy. *P.* pilosa

(2) Petals *pinkish, bifid;* pubescent, low. *P.* bifida

(3) Petals *lilac or blue;* leaves broad; stems loosely spreading, pubescent. P. divaricata

(*b*) Flowers *panicled* pink, stem tall without spots. P. paniculata

B. Flowers regular 5-parted; ovary *deeply 4-lobed* about the *common*

style; usually rough herbs, with alternate leaves; inflorescence usually 1-sided-cymose or racemose. **Borraginaceæ**

a *Corolla trumpet-form* with *open throat, blue;* filaments slender, exserted; smooth, with large leaves and cymose, showy flowers. *Mertensia* virginica

b Corolla salver-form, with the throat slightly closed, yellow, woolly bearded at the base within; plant hispid. *Lithospermum* hirtum

C. Flowers regular, 5-parted; corolla *imbricate* or *valvate* in bud; ovary *entire 2-celled; style 1;* fruit usually a many-seeded berry. **Solanaceæ**

Order XXXVII.

Asterales.—A. Flowers usually many on a *common receptacle, surrounded by an involucre; stamnes on the* corolla; *ovary 1-celled; style 2-cleft;* calyx often wanting or *greatly reduced, forming* a *pappus.* **Compositæ**

a Flowers all perfect, ligulate; *pappus white, capillary;* herbs with milky juice.

(*a*) *Flowers large, yellow;* stemless, with long lobed and toothed leaves. *Taraxicum* officinale

b Heads, with many *disc* and ray *flowers, on naked peduncles;* rays pistillate; pappus *capillary, scanty; receptacle naked;* flowers *pink or white.* *Erigeron*

(*a*) Perennial, hairy; leaves mostly near the base of stem.

(1) Flowers large, few, (1-9); rays about 50, light bluish-purple. *E.* bellidifolium

SPECIAL GLOSSARY.

acaulescent: apparently stemless; the stem being very short or subterranean.
achenium: a one-seeded, seed-like fruit.
acute: merely sharp-pointed, or in a point less than a right angle.
adelphous (stamens): joined filaments.
adnate: the anther fixed by its whole length to the filament or its prolongation.
akene or *akenium:* see achenium.
albumen the nutritious matter stored up in the seed.
alternate (leaves): arranged one after another at different heights on the axis
ament: see catkin.
amorphous: shapeless; without any definite form.
andrœcium: a name for the stamens taken together.
androus: referring to stamens.
annual (plant): fruiting the year it is raised from the seed and then dying
anterior: in the blossom, is the part next the bract, *i.e.*, external.
anther: the region of the stamen which bears the pollen.
antheridium: a reproductive organ corresponding to the anther of flowering plants
antrorse: directing upwards or forwards.

apetalous: destitute of petals.
apocarpous: (pistils): when the several pistils of the same flower are separate.
arboreous, arborescent: tree-like, in size or form.
awn: the bristle or beard of barley, oats, etc.; or any similar appendage.
axis: the organ round which others are attached; the root and stem.
axil: the angle on the upper side between a leaf and the stem.
axillary (buds, etc.): occurring in an axil.
berry: a fruit pulpy or juicy throughout.
bidentate: having two teeth (not twice or doubly dentate).
bifid: two-cleft to about the middle.
bilabiate: two-lipped, as the corolla of sage.
bilocular: two-celled, as most anthers, the pod of fox glove, most saxifrages, etc.
bisexual: with both stamens and pistils,
bract: a small leaf associated with a flower.
bractlet: a bract seated on the pedicel or flower-stalk.
bulb: a leaf-bud with fleshy scales, usually subterranean.
bulbous: bulb-like in shape, etc.
calyx: the outer set of the floral envelopes or leaves of the flower.
calyx-tube: the tube formed by the union of the sepals.
capillary: hair-like in shape; as fine as hair or slender bristles.
capsule: a pod; any dry, dehiscent seed-vessel.
capitate: having a gobular apex, like the head of a pin.
carpel: simple pistil; one of the parts of which a compound pistil is composed.
carpellary: belonging to a carpel.
cartilaginous: firm and tough, like cartilage in texture.
catkin: a scaly deciduous spike of flowers, an ament.
caulescent: having an obvious stem.
cell: the cavity of an anther, ovary, etc.
chlorophyll: the green coloring matter in plants.
circinate: rolled inwards from the top, like a crosier, as the fronds of ferns.
clustered: leaves, flowers, etc., aggregated or collected into a bunch.
commissure: the line of junction of two carpels, as in the fruit of umbelliferæ.
compound: composed of two or more distinct parts.
cone: the fruit of the pine family.
conjugate: coupled; in single pairs.
connate: united or grown together from the first.
convolute: rolled up lengthwise, as the leaves of the plum in vernation.
cordate: heart-shaped.
corm: a solid bulb, like that of crocus.
corolla: the leaves of the flower within the calyx.
corona: a coronet or crown, an appendage at the top of the claw of some petals.
corymb: a sort of flat or convex flower-cluster.
cotyledons: the first leaves of the embryo.
crenate: the edge scalloped into rounded teeth.

cryptogamous: relating to cryptogams, or flowerless plants.
culm: a straw; the stem of grasses and sedges.
cylindrical form: as that of stems, etc., which are round, and tapering.
cylindraceous: approaching to the cylindrical form.
cyme: a cluster of centrifugal inflorescence.
cymose: furnished with cymes or like a cyme.
deciduous: falling off, as a calyx and corolla which fall before the fruit forms.
decompound: several times compounded or divided.
definite: when of a uniform number, and not above twelve or so.
dehiscence: the mode in which an anther or pod regularly bursts or splits open.
dehiscent: opening by regular dehiscence.
dentate: toothed.
diadelphous (stamens): united by their filaments in two sets.
diandrous: having two stamens.
dicotyledonous: having a pair of cotyledons.
digitate (fingered): leaflets of a compound leaf borne on apex of the petiole.
dimerous: made up of two parts, or its organs in twos.
diœcious: where the stamens and pistils are in separate flowers on different plants.
disk: the face of any flat body; the central part of a head of flowers.
divided (leaves, etc.): cut into divisions extending about to the base or the mid rib.
drupe: a stone-fruit.
elaters: threads mixed with the spores of liverworts.
embryo: the rudimentary, undeveloped plantlet in the seed.
endosperm: (see albumen).
entire: the margins not at all toothed, notched or divided, but even.
epigynous: upon the ovary.
epiphyte: a plant growing on another plant, but not nourished by it.
equitant: leaves folded longitudinally, and overlapping without any involution.
evergreen: holding the leaves over winter and until new ones appear.
exserted: protruding out of, as the stamens out of the corolla.
extrorse: the anther turned outwards and opening on the outer side.
fascicle: a compact cluster.
fascicled: growing in a bundle or tuft, as the leaves of a pine and larch.
fertile: capable of producing fruit or good pollen.
filament: the stalk of a stamen; also any slender, thread-shaped appendage.
flabelliform: fan-shaped; broad, rounded at the summit and narrowed at the base.
fleshy: composed of firm pulp or flesh.
floating: swimming on the surface of the water.
floral envelopes: the leaves of a flower.
foliate: relating to or bearing leaflets.
follicle: a simple pod, opening down the inner suture.
fruit: the matured ovary and its contents.
fugacious: soon falling off or perishing.
funnel-form: expanding gradually upwards like a funnel.

gamopetalous: of united petals; same as monopetalous, and a better word.
gemmation: state of budding, or the arrangement of parts in the bud.
germ: a growing point; a young bud; sometimes the same as embryo.
germination: the development of a plantlet from the seed.
glabrous: smooth, *i. e.*, having no hairs, bristles, or other pubescence.
glands: small-cellular organs which secrete oily or aromatic or other products.
glaucous: covered with a bloom, viz., with a fine white powder that rubs off.
glumes: the husks of floral coverings of grasses, as bracts of each spikelet.
glumaceous: glume-like or glume-bearing.
gynœcium: a name for the pistils of a flower taken altogether.
habitat: the situation in which a plant grows in a wild state.
herbaceous: of the texture of common herbage.
hermaphrodite (flower): having both stamens and pistils in the same blossom.
hispid: bristly; beset with stiff hairs,
hexamerous: its parts in sixes.
hypogynous: inserted under the pistil.
imbricate: overlapping like shingles.
incomplete flower: wanting calyx or corolla.
indehiscent: not splitting open.
inferior: growing below some other organ.
inflated: turgid and bladdery.
inflorescence: the arrangement of flowers on the stem.
internode: the part of a stem between two nodes.
introrse: turned or facing inwards, *i. e.*, towards the axis of the flower.
involucre: a whole or set of bracts around a flower, umbel or head.
involucel: a partial or small involucre.
irregular: parts of same whorl, unlike.
isomerous: organs of a flower composed of an equal number of parts.
keel: a projecting ridge on a surface like the keel of a boat.
keeled: furnished with a keel or sharp, longitudinal ridge.
kidney-form: resembling the outline of a kidney.
labiate: same as bilabiate or two-lipped.
lamina: a plate or blade.
lanceolate: lance-shaped.
leaflet: one of the divisions or blades of a compound leaf.
legume: a simple pod, dehiscent into two pieces like that of the pea.
ligule: the strap-shaped corolla in many compositæ.
ligulate: tongue-shaped.
linear: narrow and flat, the margins parallel.
membranaceous: of the texture of membrane; thin and more or less translucent.
micropyle: the closed orifice of the seed.
monodelphous: stamens united by their filaments into one set.
monocotyledonous (embryo): with only one cotyledon.
monœcious (flower): having stamens or pistils only.

monopetalous (flower): with the corolla of one piece.
monosepalous: a calyx of one piece, *i. e.*, with the sepals united into one body.
morphology: the form and structure which an organ (say a leaf) may assume.
netted-veined: furnished with branching veins forming net work.
node: a knot; the joints of a stem or the part whence leaves spring.
obcordate: heart-shaped with the broad and notched end at the apex.
opposite: on opposite sides of the stem from each other (*i. e.*, in pairs).
oval: broadly elliptical.
ovary: that part of the pistil containing the ovules or future seeds.
ovate: shaped like or having the outline of an egg.
palmate: parts spread like the hand with the outspread fingers.
panicle: an open cluster; like a raceme but more or less compound.
pappus: thistle-down.
pappose: forming pappus.
parallel-veined (leaves): the veins running parallel to the mid-rib.
parietal (placentæ, etc.): attached to the walls of the ovary.
pedate: palmate or palmately cleft, with the side divisions again cleft.
pedicel: the stalk of each particular flower of a cluster.
peduncle: a flower-stalk, whether of a single flower or of a flower-cluster.
peltate: shield shaped.
pentamerous: with its parts in fives or on the plan of five.
perennial: lasting from year to year.
perfect (flower): having both stamens and pistils.
perianth: floral envelopes, not readily distinguishable as calyx and corolla.
pericarp: the ripened ovary.
perigynium: a body of bracts borne around the pistil.
perigynous: the petals and stamens borne on the calyx.
persistent: remaining beyond the period when such parts commonly fall.
petiole: the stem or stalk at the base of a leaf.
petal: a leaf of the corolla.
petaloid: petal like; resembling or colored like petals.
pinnate (leaf): with leaflets arranged along the sides of a common petiole.
pistil: the seed-bearing organ of the flower.
placenta: the surface or part of the ovary to which the ovules are attached.
pollen: the fertilizing powder of the anther.
polygamous: having both perfect and unisexual flowers.
polypetalous: petals distinct or separate (whether few or many).
pome: a fleshy many-celled fruit such as the apple.
prickles: sharp elevations of the bark, coming off with it, as of the rose.
pubescent: hairy, or downy, especially with fine and soft hairs or pubescence.
pungent: very hard, and sharp-pointed; prickly-pointed.
raceme: a flower-cluster having stalked flowers on a common axis.
racemose: bearing racemes, or raceme-like.
radical: belonging to the root or apparently coming from the root; first root.

ray : the marginal flowers of a head or cluster when different from the rest.
receptacle : the axis or support of a flower or head of flowers.
recurved : curved outwards or backwards.
reflexed : bent outwards or backwards.
regular : having all the parts of the whorl, similar.
rhizome : a root-stock.
root-stock : root-like trunks or portions of stems on or underground.
runner : a slender, prostrate branch, rooting at the end or joints as the strawberry.
salver-shaped : border spreading at right angles to tube, as the corolla of phlox.
samara ; a winged fruit or key, as of maple, ash, or elm.
scale (buds and bulbs) : modified leaf-like structures.
scape : a peduncle, rising from the ground, or near it, as of the stemless violets.
scarious : thin, dry, and membranous.
segment : a subdivision or lobe of any cleft body.
sepal : a leaf or division of the calyx.
serrate : margin cut into teeth, pointing upwards.
sessile : sitting; without any stalk, as a leaf destitute of a petiole.
simple : of one piece; opposed to compound.
sinus : the re-entering angle or space between two lobes or projections.
solitary : single; not associated with others.
spadix : a fleshy spike of flowers.
spadaceous : resembling or furnished with a spadix.
spathe : a bract which inwraps an inflorescence.
spathaceous : resembling or furnished with a spathe.
spike : an inflorescence like a raceme, only the flowers are sessile.
spikelet : a small or secondary spike; the inflorescence of grasses.
spore : a body resulting from the fructification of cryptogamous plants,
spur : a projection of the flower, resembling a spur.
staminate : furnished with stamens.
sterile : barren or imperfect.
stigma : the porous end or surface of the pistil which receives the pollen.
stipules : the appendages, one on each side of the base of certain leaves.
style : the part of the pistil which bears the stigma.
syncarpous (fruit or pistil) : composed of several carpels consolidated into one.
tap-root : a root with a stout, tapering body.
tendril : a thread-like structure used for climbing.
terete : long and round, same as *cylindrical*, only it may taper.
terrestrial : living on the land.
tetramerous : with its parts or sets in fours.
thallus : a plant-body having no true stem, leaves and roots.
thyrse or *thyrsus :* a compact and pyramidal panicle.
torus : the receptacle of the flower.
trimerous : with its parts in threes.
triple-ribbed : midrib with branches near the base of the leaf, as in sunflower.

tuber : a thickened portion of a subterranean stem or branch, as a potato.
tubular : hollow and of elongated form.
twining : ascending by coiling around a support, like the hop.
umbel : the umbrella-like form of inflorescence.
umbellate : in umbels.
unisexual : having stamens or pistils only.
valve : one of the pieces into which a dehiscent pod, or any similar body, splits.
valvate : opening by valves.
vascular : containing vessels, or consisting of vessels, such as ducts.
vein : the small rib or branch of the frame-work of leaves.
vesicle : a little bladder.
vine : any trailing or climbing stem.
viscous : having a glutinous surface.
whorl (leaves, etc.): arranged in a circle round the stem.
wing : any membranous expansion.

LABORATORY EQUIPMENT AND TECHNIQUE.

LABORATORY EQUIPMENT.†

A biological laboratory should be provided with a sink, water, and, if possible, gas. The tables, if properly constructed, will each accommodate four pupils at a time, and this number four or five times a day, providing each pupil with a separate locker. There should be at least half as many compound microscopes as the number of pupils working in the laboratory at one time, two pupils using a microscope in common. It is more satisfactory, however, that each pupil in the class should have the exclusive use of a microscope.* The laboratory should be provided with a microtome, paraffin bath, and a set of chemical reagents.

THE PUPILS' EQUIPMENT.

Each pupil should provide himself with the following named articles: —

(1) A scratch-book and soft pencil.
(2) A hand towel and sponge.
(3) A set of laboratory tablets, consisting of a drawing tablet, a writing tablet, a pair of covers and fasteners, a hard pencil (HHH or HHHH).
(4) A copy of the Laboratory Manual.

* The Chicago High Schools import an outfit which, duty free, costs $15. It consists of Leitz's stand, No. V; ocular, No. 2; objectives, No. 3 and No. 6, giving magnifying powers, respectively, of about 68 and 285 diameters.

† D. C. Heath & Co., Chicago, have issued a pamphlet entitled *The Biological Laboratory in Secondary Schools*, which offers suggestions concerning the arrangement and equipment of a laboratory. On application, this pamphlet is sent free to teachers and principals of schools.

(5) A simple set of tools,* consisting of a pair of sharp-pointed scissors, a pair of forceps, a scalpel, a blow-pipe, a pair of needles with handles, and a hand magnifier.

ALCOHOL.††

Alcohol † is the most important reagent in the biological laboratory: the commercial alcohol varies from 90% to 95% in strength; absolute alcohol, 100%, is needed only in small quantities, and is usually put up in pound bottles. Some authors refer to "Cologne spirits," which is 90%. Alcohol is much used in lower grades, which can be prepared from the higher grades, by adding distilled water, either by the alcoholmeter, or in certain proportion by volume.

To prepare 190 cubic centimetres of the various grades from 95 %, or the standard commercial alcohol, the following table of proportions is sufficiently accurate for ordinary use: —

To make.	*Take of* 95%.	*Add* H_2O.
90%,	180 c.c.	10 c.c.
70%,	140 c.c.	50 c.c.
50%,	100 c.c.	90 c.c.
35%,	70 c.c.	120 c.c.

The above grades should be kept on hand ready for use. Alcohol has a wide range of uses. In addition to its general use in preparing other reagents, it is also used in killing, fixing, hardening, and preserving tissue. Nothing lower than 70 % is a safe preserving agent. Material intended for histological purposes should be stored in 90 %. Material which has once been passed to 90 % may remain in lower grades for staining, without injury. As a good macerating agent 30 % may be used. Alcohol used

* Richards & Co., Limited, and E. H. Sargent & Co., Chicago, are manufacturers of these sets. Retail price, $1.00.

† Schools, by first complying with certain legal formalities of the United States Revenue laws, are permitted to withdraw alcohol from bonded warehouses free of the revenue tax. By this means it may be had at about 75 cents per gallon, instead of the usual price of about $2.50 including internal revenue.

†† See *Formalin*, on page 202.

in hardening or dehydrating tissue, and that used in preserving and storing material, will gradually become of a grade too low to be of practical use. Such alcohol and other waste alcohol should not be thrown away, but may be redistilled.

Alcoholic Material. — Material which has been for some time in alcohol should be placed in water for a little while before it is studied, especially if dissections are to be made. When alcoholic material acquires a disagreeable odor, a few drops of the oil of Cassia may be added to the alcohol containing such material.

LIST OF REAGENTS.

Only a few of the more important reagents and formulas are given in this list. The attention of the instructor is called to the references at the close of this list, to the special works on microscopic technique.

In preparing mixtures requiring definite per cent., into which ingredients enter both by weight and volume, 1 gramme is equal to 1 cubic centimetre.

ALBUMEN FIXATIVE (*Mayer's*).

Formula. — Take 50 c.c. glycerine with 50 c.c. white of egg and add 1 gramme salicylate of soda. Shake together and filter.

Use. — Same as collodion fixation (*q.v.*).

ALCOHOLIC BORAX-CARMINE (*Grenacher's*).

Formula. — Take a 4 % aqueous solution of borax and add 2 to 3 % Carmine "No. 40" (2 to 3 parts carmine to 4 parts borax): add an equal volume of 70 % alcohol and allow to stand 24 hours and filter.

Use. — For tissue which has been hardened. Tissue should pass from 35 % alcohol into this stain. A good general stain. Decolor with 35 % acidulated alcohol.

ALUM COCHINEAL (*Czokor's*).

Formula. — Rub together in a mortar 7 grammes of cochineal and 7 grammes calcined alum. Add 700 c.c. distilled water

and boil down to about 400 c.c. When cool add about 5 drops of carbolic acid. Filter several times.

Use. — A good nuclear stain on animal tissue. Apply several hours. Wash out stain with distilled water and pass through grades of alcohol.

ANILINE DYES (*green*, *blue*, *violet*, *red*, etc.).

Formula. — Strong alcoholic or aqueous solutions are prepared.

Use. — Valuable chiefly in staining plant tissue. Apply a few minutes to 24 hours. Wash out stain with water.

ACETIC ACID.

Formula. — Dissolve 10 c.c. glacial acetic acid in 100 c.c. distilled water: add enough distilled water to make the solution 1 litre.

Use. — For clearing tissue and rendering nuclei in fresh plant tissue more distinct.

ACIDULATED ALCOHOL.

Formula. — To 100 c.c. of 35 % alcohol add from 4 to 6 drops of hydrochloric acid. Same with 70 % alcohol.

Use. — For removing excess of stains.

CANADA BALSAM.

Formula. — Take the best grade of Canada balsam or balsam fir, bake slowly until thoroughly dry; powder and dissolve in chloroform, benzol, or turpentine.

Use. — Mounting medium. Tissue must be perfectly dehydrated with absolute alcohol and cleared with clove oil or other clearing agent before mounting. Keep in wide-mouthed bottles, well stoppered. Apply by drops with glass rod.

CARMINE INJECTION FLUID.

Formula. — Rub up carmine in distilled water and add ammonia drop by drop, till the carmine is dissolved. Filter, and then evaporate over a gentle heat, while constantly stirring to get rid of the ammonia. The residue is to be dissolved in camphor water.

Use. — For injecting small animals or portions of animals. Shake thoroughly before use.

CHLOROFORM.

Use. — For killing all kinds of animals. Use in tight box or jar. Used as liquid or vapor.

CHROMO-NITRIC ACID (*Perenyi's Fluid*).

Formula. — Take 4 volumes 10 % nitric acid : add 3 volumes 90 % alcohol ; add 3 volumes 0.5 % chromic acid. Allow to stand several hours before using. The mixture should assume a violet hue.

Use. — For general use one of the best fixing and hardening reagents. Apply from 2 to 5 hours. For ova from 20 minutes to 2 hours.

CHROMIC ACID (*Crystals of* $Cr.O_3$).

Formula. — Prepare a 5 % aqueous stock solution. Only the weaker solutions are in general use, which may be readily prepared from the stock solution.

Use. — For fixing plant tissue use a 1 % to 3 % solution. For animal tissue 0.5 % to 1 % solution. Material should be thoroughly washed in water before passing through grades of alcohol.

For decalcifying bone, a 5 % to 10 % solution, with or without nitric acid, is used.

COLLODION FIXATIVE (*Schällibaum's*).

Formula. — Take 1 part of thin collodion and 4 parts of clove oil, and shake together. Should be made up in small quantities (1 ounce).

Use. — For fixing paraffin sections to the slide. A thin film is applied with a camel's-hair brush, which may be kept in the cork of the phial containing the fixative.

CORROSIVE SUBLIMATE (*solution*).

Formula. — Prepare a saturated solution of mercuric chloride in distilled water. A litre of water dissolves about 60 to 70 grammes. No metal should be allowed to touch the solution. Remember this is a deadly poison.

Use. — For killing small organisms. Used either hot or cold. Wash material thoroughly before passing through grades. Used cold as a hardening reagent.

FOOD SOLUTION FOR GREEN PLANTS (*Sach's*).

Formula. — Distilled water, 1 gramme; potassium nitrate, 0.5 gramme; sodium chloride, 0.5 gramme; calcium sulphate, 0.5 gramme; magnesium sulphate, 0.5 gramme; calcium phosphate, 0.5 gramme. To this solution is to be added a trace of a weak solution of ferric chloride.

GELATINE INJECTION.

Formula. — French gelatine is soaked in water; when soft the superfluous water is poured off. Melt slowly and stir into it Carmine Injection Fluid or other thin insoluble coloring matter. Add a few drops of carbolic acid. Stir while cooling.

Use. — For injecting specimens which are intended for sectioning. Should be used warm. In case of large specimen it is necessary to perform the injection in a vessel of hot water.

GLYCERINE (*dilute, alcoholic, pure glycerine jelly*).

Formula. — Dilute equal parts glycerine and distilled water. Alcoholic, equal parts glycerine and 90 % alcohol. Glycerine jelly (buy prepared).

Use. — *Dilute* on vegetable tissue (1) clears; (2) withdraws water from fresh cells and shrinks protoplasm from cell-walls; (3) preserves material.

Alcoholic on vegetable tissue, softens hard alcoholic material.

Pure Glycerine is used in dehydrating, preserving, and mounting tissue. *Glycerine jelly* is a mounting medium.

HÆMATOXYLIN STAIN (*Kleinenberg's*).

Formula. — Prepare a saturated solution of calcium chloride in 70 % alcohol, adding a little alum. Filter this solution and then add from 6 to 8 volumes of 70 % alcohol. This may be regarded as a "mordant." Make a concentrated

solution of hæmatoxylin in absolute alcohol. The stain is prepared by adding to the mordant a few drops of the concentrated hæmatoxylin solution. The stain should be at least two days old before using and show a bluish violet color.

Use. — A good general stain. Remove excess of stain from tissue with 70 % acidulated alcohol.

IODINE SOLUTION.

Formula. — Dissolve 1 gramme potassic iodide in 10 c.c. of distilled water and add 0.25 gramme iodine. Dilute to 250 c.c.

Use. — Principally used on plant tissue. It turns starch blue or purple; cellulose, yellow, when acting alone; cellulose, blue, when acting with sulphuric acid (*q.v.*); turns protoplasm and nucleus brown.

MACERATING FLUID (*Schultze's*).

Formula. — Dissolve a gramme of potassium chlorate in 50 c.c. of nitric acid.

Use. — For plant tissue. The tissue should be boiled in the mixture and then thoroughly washed in water. It may also be used on temporary preparations on the slide.

MAGENTA (*stain*).

Formula. — In a litre of water dissolve .6 gramme of crystallized magenta (roseine). To the solution add 6 c.c. absolute alcohol.

Use. — For staining fresh material. Used only in temporary preparations.

NORMAL SALT SOLUTION ("*physiological salt solution*").

Formula. — To a given quantity of distilled water add 0.75 % of sodium chloride.

Use. — For retaining temporarily living or fresh animal tissue in its normal condition.

OSMIC ACID.

Formula. — Prepare a 2 % aqueous solution. Dissolve 1 gramme osmic acid crystals in 50 c.c. of distilled water.

Great care is needed in preparing and storing this reagent to avoid contact with organic matter and light.

Use. — For staining fat in tissue. For killing microscopic animals. For fixing tissue. The above solution should be reduced to one-third its strength before use.

PICRIC ACID (*saturated solution*).

Formula. — Prepare a saturated aqueous solution.

Use. — (1) For fixing plant tissue. Wash material thoroughly in water, and then pass through grades of alcohol. (2) Used in fixing animal tissue. (3) Used in preparing Kleinenberg's *Picro-sulphuric* mixture.

PICRO-SULPHURIC ACID (*Kleinenberg's mixture*).

Formula. — Take 100 c.c. saturated aqueous solution Picric acid and add 2 c.c. concentrated sulphuric acid. Allow to stand several hours, then filter and add 300 c.c. distilled water.

Use. — An excellent killing and fixing reagent. May be used *hot* or *cold*. Tissue should remain from 2 to 5 hours and pass to 70 % alcohol, which should be changed several times before material is passed to 90 %. Used also as decalcifying reagent.

PLASTER OF PARIS INJECTION.

Formula. — Fine Plaster of Paris is rubbed up with water in a mortar to the consistency of thin cream. Color to the required tint with Carmine Injection Fluid or French Blue. Strain through fine muslin. The Plaster of Paris may be mixed with a pigment and kept in stock. In making up the mass, about 1 part of Plaster of Paris to 3 parts of water should be used.

Use. — For injecting vessels, etc., of larger animals. Must be used immediately after preparation.

POTASSIC HYDRATE.

Formula. — Prepare a 5 % aqueous solution.

Use. — For clearing and bleaching plant tissue. Swells up shrivelled material and renders it plump.

SULPHURIC ACID.

Formula. — Prepare a 50 % aqueous solution, adding the sulphuric acid slowly.

Use. — In fresh plant tissue this reagent turns protoplasm brown; dissolves cellulose, but leaves protoplasm; turns cellulose blue when acting with iodine.

TURPENTINE (*pure*).

Use. — For dissolving paraffin from sections after they have been fixed to the slide. Also, clearing reagent to remove alcohol from tissue before mounting in Canada balsam.

FORMALIN.

A new hardening and preserving reagent is now taking the place of alcohol to a large extent. It is variously known as *40% solution Formaldehyde*, *Formol*, *Formalin*, and *Formolose*, and is a good preservative for both animal and plant tissue. For ordinary purposes it may be used as a 1 % to 2½ % aqueous solution.

The following works are largely or entirely devoted to microscopic and laboratory technique: —

References. — 14 — 16 — 28 — 30 — 54 — 58 — 67 — 94 — 161 — 167.

The following works devote only a limited amount of space to technique: —

References. — 5 — 6 — 17 — 21 — 24 — 26 — 43 — 45 — 65 — 106 — 125 — 127 — 137 — 147.

WORKS OF REFERENCE.

THE following list of works, intended for reference and collateral reading, will be found helpful to both pupil and instructor. The list, as will be seen, is arranged in alphabetical order by authors. The references which occur at the close of each laboratory study are made by the serial number which appears in the column along the left margin.

The numbers enclosed in parentheses, appearing to the right of the titles, refer to the List of Publishers on page 208.

1. AGASSIZ. Seaside Studies in Natural History. 1865. (18.)
2. ALLEN. On the Color of Flowers. 1882. (24.)
3. Common Sense Science. 1887. (23.)
4. APGAR. Trees of the Northern United States. 1892. (1.)
5. ARTHUR, BARNES, and COULTER. Handbook of Plant Dissection. 1886. (17.)
6. ATKINSON. Biology of Ferns. 1894. (24.)
7. AVELING. An Introduction to the Study of Botany. 1891. (24.)

8. BADENOCK. Romance of the Insect World. 1894. (24.)
9. BALFOUR. Elements of Botany. 1876. (24.)
10. Manual of Botany. 1875. (24.)
11. Treatise on Comparative Embryology. 1891. (24.)
12. BASTIN. Elements of Botany. 1890. (11.)
13. BATES. The Naturalist on the River Amazon. 1892. (3.)
14. BEALE. How to use the Microscope. 1880. (4.)
15. BEDDARD. Animal Coloration. 1892. (24.)
16. BEHRENS. Guide to the Microscope in Botany. 1885. (6.)
17. BENNET and MURRAY. A Handbook of Cryptogamic Botany. 1889. (22.)
18. BESSEY. Botany for High Schools and Colleges. 7th ed., 1889. (17.)
19. Elements of Botany. 4th ed., 1889. (17.)
20. BIDGOOD. Elementary Biology. 1893. (22.)
21. BOWER. A Course in Practical Botany. 3d ed., 1891. (24.)
22. BROOKS. Handbook of Invertebrate Zoölogy. 1882. (6.)

23. BURRILL and EARLE. Parasitic Fungi of Illinois. 1887. (35.)
24. BUMPUS. Course in Invertebrate Zoölogy. 1892. (30.)

25. CALDERWOOD. Evolution and Man's Place in Nature. 1893. (24.)
26. CAMPBELL. Elements of Structural and Systematic Botany. 1891. (13.)
27. Text-book of Elementary Biology. 1893. (24.)
28. CARPENTER. The Microscope and Its Revelations. 7th ed., 1891. (4.)
29. Vegetable Physiology. 1894. (24.)
30. CLARK. Practical Methods in Microscopy. 1894. (15.)
31. CLAUS and SEDGWICK. Text-book of Zoölogy. 2 vols. 1890. (24.)
32. CLODD. The Story of Creation. 1889. (22.)
33. COMSTOCK. Introduction to Entomology. 1888. (36.)
34. COLTON. Elementary Course in Practical Zoölogy. 1888. (15.)
35. COOKE and BERKLEY. Fungi, their Nature and Use. 1874. (3.)
36. COOKE. Introduction to Fresh Water Algæ. 1890. (3.)
37. COPE. The Origin of the Fittest. 1887. (3.)
38. COX. Protoplasm and Life. 1890. (16.)
39. CREEVEY. Recreations in Botany. 1894. (14.)

40. DARWIN and ACTON. Physiology of Plants. 1894. (8.)
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ascospores — Gr. *askos*, bag, 120.
ascomycetes — Gr. *askos*, a bag; *mukēs*, a mushroom, 174.
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os innominatum — L. *os*, bone; *in*, not; *nomen*, name, 103.
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ostia — L. *os*, mouth, 30.
ovum — L. *ovum*, an egg, 8.
ovule — L. *ovule*, a little egg, 152.
ovary — L. *ovum*, an egg, 7, 40, 63, 79, 95, 160.
oviducts — L. *ovum*, egg; *ductus*, a duct, 31, 63, 79, 95.
oviparous — L. *ovum*, egg; *pario*, I produce, 90.
ovipositor — L. *ovum*, egg; *positum*, to place, 34.
oxalis — L. *oxus*, sour, 184.
oyster, 51.

palatines — L. *palatus*, the palate, 57.

premolar — L. *pre*, before; *molares*, the grinders, 112.
primaries — L. *primus*, first, 105.
primates — L. *primus*, first, 172.
primulales — *primus*, first, 180; primulaceæ, 186.
proboscidea — L. *proboscis*, a trunk, 172.
process, 67; tentacular —, 48.
prosimiæ — L. *pro*, before; *simia*, ape, 172.
prostomium — Gr. *pro*, before; *stoma*, mouth, 19.
prothallium — Gr. *pro*, before; *thallos*, a sprout, 141, 146.
prothorax — Gr. *pro*, before; *thorax*, chest, 36.
protista — Gr. *prōtos*, first, 169.
protococcus viridis — Gr. *prōtos*, first; *kokkos*, a berry; L. *viridis*, green, 117.
protonema — Gr. *prōtos*, first; *nema*, thread, 145.
protophyta — *prōtos*, first; *phuton*, plant, 120, 173.
protoplasm — Gr. *prōtos*, first; *plasma*, what has been formed, 1.
protopterus — Gr. *prōtos*, first; *pteron*, wing, 171.
protozoa — Gr. *prōtos*, first; *zoön*, an animal, 3, 169.
proximal — L. *proximus*, nearest, 7.
prunus — L. *prunum*, a plum, 185.
pseud-acacia — Gr. *pseudes*, false; L. *acacia*, a thorn, 186.
pseudopodia — Gr. *pseudes*, false; *pous*, foot, 1.
pteridophyta — Gr. *pteron*, wing; *phuton*, plant, 146, 174.
pteris aquilina — Gr. *pteris*, fern; L. *aquila*, eagle, 140.
pteropoda — Gr. *pteron*, wing; *pous*, foot, 171.
pterylæ — Gr. *pteron*, a wing, 105.
pubis — L. *pubis*, 94.
pubescens — L. *pubescius*, hairy, 183, 184.
puff-balls, 133.
pupil — L. *pupilla*, a little girl, the pupil of the eye, 56.
pyloric — Gr. *pulores*, a gate-keeper; — chamber, 31; — cœca, 61; — duct, 14; — sac, 14.
pyrenoid — Gr. *purēn*, the stone of fruit, 123.

quadrate — L. *quadratus*, squared, 99.
quadrupeds — L. *quadrupes*, four-footed, 109.
quahog, an Indian name, 42.
quercus — L. *quercus*, an oak, 185.
quernales — L. *quercus*, an oak, 178.
quill, 106; — feathers, 105.
quinquefolia — L. *quinque*, five; *folium*, leaf, 184.

rostrum — L. *rostrum*, a beak, 25.
rubiales — L. *ruber*, red, 181.

saccharomyces cereviseæ — L. *saccharum*, sugar; *mukēs*, a fungus; *cervesia*, beer, 117.
sacrum — L. *sacrum*, sacred, 76.
sacral, 101.
salamander — Gr. *salamandra*, supposed to be a kind of lizard capable of extinguishing fire, 89.
salivary glands — L. *saliva*, spittle, 41.
salpa — Gr. *salpē*, a kind of stock-fish, 171.
sand-dollar, 16.
santalales — L. *santalis*, a kind of palm-tree, 178.
sapindales — L. *sapo*, soap, 178; sapindaceæ, 185.
saprophyte — Gr. *sapros*, putrid; *phuton*, plant, 121.
scalariform vessels — L. *scala*, a ladder; *forma*, shape, 144.
scales, 60, 137; scale-bearers, 149; — leaves, 149.
scandens — L. *scandens*, climbing, 184.
scansores — L. *scando*, I climb, 172.
scaphopoda — Gr. *skaphē*, a bowl; *pous*, foot, 171.
scapula — L. *scapula*, shoulder-blade, 75, 93, 102.
schizomycetes — Gr. *schizo*, I cleave; *mukēs*, a fungus, 173.
sciatic plexus — L. *sciatica*, pertaining to the hip; *plexus*, twisted, 85.
sclerenchyma — Gr. *sklēros*, hard; *enchuma*, tissue, 143.
scotch pine, 147.
scutellum — L. *scutellum*, small shield, 164; scutella, 106; scutellate, 106.
sea-anemone — Gr. *anemos*, the wind, 9.
sea-cucumber, 16.
sea-urchin — L. *ericius*, a hedgehog, 16.
secondaries, 105.
seedlings, 162.
seeds, 153 — seed-coats, 163.
segments, 26.
selachii — Gr. *selachos*, a cartilaginous fish, 171.
semi-liquid, 119.
sensation — L. *sentio*, I discern by the senses, 2.
sepals — L. *sepes*, a hedge or fence, 158.
septa — L. *septum*, a partition, 20, 125.
sessile — L. *sessile*, in a sitting posture, 157.
setæ — L. *seta*, a stiff hair, 19.