WILLIAM C. BEAVER, Ph.D., D.Sc.
Professor of Biology, Wittenberg University,
Springfield, Ohio

Workbook and laboratory manual in general biology

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Preface to sixth edition

ALTHOUGH DESIGNED TO BE USED with the author's *General Biology,* this manual is suitable for many beginning college courses in biology. A close correlation between laboratory and classroom work is possible because the exercises in the manual are in the same sequence as the chapters in the text.

The exercises are so arranged that a choice may be made in the selection of the wide range of work, thus permitting emphasis on such parts as the instructor may desire to meet the requirements for a variety of courses. In some instances, alternate exercises and a choice of work permit flexibility for courses of a year, a semester, or a quarter.

In certain exercises a scientific method of presentation is followed in order to give the student important training in the solutions of problems. If mastered properly and practiced accurately, such a method of working and thinking will be of value not only in science but in many other disciplines as well, including the solution of problems of everyday living. All work in laboratory and field should be considered as problems to be solved. These problems should be kept clearly in mind, working hypotheses should be proposed, careful observations made, pertinent data and information recorded accurately, and logical conclusions drawn. The exercises require some thinking and reasoning by the student and the aim is not merely a mechanical execution and interpretation of instructions but also the development of comprehension and insight.

Some of the exercises are presented so that certain topics may be considered carefully and accurate reports written. These reports may be handed in or they may serve as the basis for oral reports or group discussions, even in class if laboratory time is lacking.

Some new and/or revised exercises include an early history and development of natural science; molecular and cellular biology; meiotic cell division in plants and animals; volvocine series of green algae; kinds of fruits; experiments on such living organisms as paramecia, hydras, rotifers, earthworms, crayfishes, etc.; additional biochemical and biophysical phenomena, including blood typing, photosynthesis, chromatography, plant hormones, respiration, viability of seeds, etc.; special problems in genetics, including sex-linked traits, lethal genes, and multiple alleles; the fetal pig which may be studied in place of, or in addition to, the frog. Certain other exercises have been rearranged and combined for greater efficiency in presentation. An attempt has been made to develop a proportionate balance between physiologic, experimental, and morphologic exercises.

It is believed that principles can be learned more easily and be more meaningful if the student actually proves them for himself through a scientific study of certain biologic phenomena and selected species of plants and animals. A study of facts and phenomena without illustrating the principles involved in the formation of accurate conclusions is stopping short of the goal. Since drawings should encourage accurate observation and recording of facts, the number and specific type of drawings in some instances may be left to the instructor who may base his selections on student qualifications and purposes of the course. In all instances, drawings should be made to help the student rather than merely to fulfill a laboratory requirement.

Simple keys for the identification and classification of both plants and animals are given in the Appendix, together with a list of materials and solutions needed for each exercise.

The pages of the manual are perforated for removal and punched for replacement after being corrected.

As in past editions, I am indebted to many individuals whose suggestions have contributed to improvements made in this edition. Suggestions for further improvements will be welcomed from the instructors and students who use this manual.

SPRINGFIELD, OHIO

William C. Beaver

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Workbook and laboratory manual in general biology

General instructions

General

A LABORATORY (L, *laboratorio,* work) is a place in which to work. Success depends largely upon your attitude toward your work and upon your ability to work independently. You will be supplied with materials and specimens which are the foundation of your work. Carefully follow the instructions given in your laboratory manual unless otherwise directed. Carefully study each specimen and secure all the information concerning it you possibly can. Be alert in your work and learn to observe details as well as general relationships. Constantly be on the lookout for things which are not described in the manual at all or which vary from the description given. At the end of each laboratory period place all specimens, equipment, slides, microscopes, etc., in their proper places. Clean your table so that students of the next section will have a clean place to work. Hand in your work at the end of each period unless otherwise directed. Place your name, section number, and date on each page and clip together all pages for each exercise. Credit for each exercise will be determined in part by punctuality.

Drawings

Drawings are made in order to learn how to see things accurately. All drawings and labels are to be made with well-sharpened drawing pencils (3H or 4H hardness). For original drawings place your specimen in the position you wish to draw it. Measure parts accurately and draw them to scale. Near each drawing express the magnification or the reduction in size by such symbols as 440× (if magnified 440 times) or ¼× (if drawn one-fourth actual size). Never draw from memory. Locate your drawing on the page so that it will be spaced properly from the margins and will leave room for the labels. Label lines should all be parallel with the edges of the paper and with each other. Labels should be printed neatly and should not be more conspicuous than the drawing itself. You need not be an artist in biology because most of your drawings are to be accurate records of your observations rather than "works of art." An accurate, semidiagrammatic drawing may be worth more than an inaccurate, artistic one. Each drawing should be accurate, complete, and neat. Make drawings large enough to show details clearly. Check over your drawing before handing it in to be sure that everything has been done properly.

For the drawings which are to be made be sure to observe all structures in your specimen to which reference is made in the drawing. Remember that a drawing is not an end in itself but a means to an end, namely, the accurate observing and recording of information and data which because of the drawing will be of greater use to you in the future. Form the habit of seeing clearly what is to be drawn and then drawing neatly and accurately.

Answers to questions

When a question occurs to you (1) attempt to answer it yourself, either from your specimen or from the knowledge you possess, (2) attempt to find the answer yourself from other references, (3) secure the help of the instructor. Follow this order, always trying to answer as many of your questions yourself as possible because someone may not always be available to answer your questions in the future. In case you cannot secure the answer the instructor will help you, either by answering the question directly or, preferably, by directing you so that you can secure it for yourself. Answers are to be complete and accurate yet as brief as completeness and accuracy will permit.

Part One

INTRODUCTORY BIOLOGY

1
A method used in science

ONE OF THE BENEFITS of taking a laboratory course such as biology is the training secured in the direct and accurate observation of facts and materials rather than reading or hearing about them. Another benefit is the development of a **scientific method** for solving problems not only in biology but also in many other fields. A scientific method may not be a foolproof procedure in all investigations, but, if all steps are followed as closely and correctly as possible, the percentage of error in the conclusions drawn will be reduced to a minimum. Each period in the laboratory or field should be considered as a planned period of investigation in which the student applies his innate curiosity in the accurate observation of facts and the acquisition of data, both of which are accurately and scientifically recorded and evaluated. A brief summarization of a **scientific method** may be stated as follows.

1. Clear recognition and accurate statement of problem to be solved

The first step in a scientific method must be the **proper awareness and clear recognition of the specific problem or situation to be solved.** The problem or condition being considered must be clearly in mind and accurately stated so that irrelevant yet closely related problems do not enter unnecessarily. However, at times the partial or complete solution of another problem may assist in the solution of the specific problem which we are attempting to solve. Great care must be taken to eliminate impertinent facts and conditions unrelated to our specific problem, yet advantage must be taken of every factor that may help in its solution. After the problem is clearly recognized and accurately stated the next step follows.

2. Accurate preliminary observations and collections of pertinent data and information

This step includes preliminary studies of available pertinent information and data to ascertain what is already known about the problem or condition being investigated. This step is naturally not exhaustive in its scope but merely lays a foundation for the next. This step might include reading, preliminary investigations and observations, gathering suggestive information from reliable sources and persons, etc. After this preliminary work has been done as accurately as possible we are ready for the next step.

3. Formulation of hypothesis based on limited information available at the time and determination of methods of investigation

A hypothesis might be considered as an assumption or speculation, as yet unproved, which may be a tentative or suggested explanation or conclusion regarding the problem being considered. It is sometimes called a **working hypothesis** because it is from this step that we work forward. The better the available preliminary information and the better the skill in making a hypothesis, the better the latter will be. A hypothesis may be the suggestion of a cause which may produce a certain effect, although it is not yet proved. Sometimes only one hypothesis for a given problem can be suggested, whereas for other problems many hypotheses may occur to us. No hypothesis, even though it may appear insignificant at the moment, should be ignored. Each hypothesis must be considered, eliminating those which are not proved, and possibly substituting new ones as progress is made. Hypotheses are sometimes called merely "good guesses," or "hunches," but it matters little what they are called as long as they are productive and lead us toward our desired goal correctly.

Another important phase of our technic is the decision on **methods of investigation** whereby we decide how and where additional, reliable, and pertinent data and information can be secured. Often the correct solution of a problem depends on where and how the additional information has been secured. In some problems the devising of the proper methods of investigation may require broad practical training, imagination, special technics, or even elaborate apparatus or equipment. In all cases the information and data must be sufficiently extensive to be truly representative (or "cross section") in order to reduce the chance effects of unusual differences or variations found in a few instances or individuals. The more methods of investigations that are considered, probably the better and more complete will be the data and information which are collected. After hypotheses have been formulated and logical methods of investigation have been approved the next step follows.

4. Testing correctness (verification) of hypothesis by collection of additional pertinent data and information

After a hypothesis has been proposed additional data and information must be accurately collected to prove or disprove the hypothesis. If the information collected disproves our hypothesis, another must be proposed and tested. A hypothesis may be tested (1) through additional accurate observations and investigations, (2) through controlled scientific experiments if such can be performed in this particular problem, or (3) by a combination of these two.

If a scientific experimental method of investigation is used, it is highly desirable to utilize the so-called **control group** of organisms or data in which a separate group is observed under conditions identical with the experimental group, except that the one condition being examined is not applied or present in the so-called control group. All factors except the one which we are attempting to discover are duplicated carefully in the controls. Only one variable should be permitted between the experimental and control groups at any one time. It is evident that controlled scientific experiments cannot be employed in the solution of certain problems so that other accurate procedures must be employed. After data and information pertinent to our problem have been secured we go on to the next step.

5. Organization, correlation, and evaluation of collected data and information to show relationships and usefulness in solution of problem

As relevant data and information are collected they must be precisely recorded in such ways that accurate and meaningful revelations will be secured from which logical conclusions can be drawn. All measurements, records, interpretations of data, or "case histories" must be scientifically accurate and sufficiently broad and comprehensive to be reliable. The careful and accurate collection and recording of the facts may make the difference between a problem being solved correctly or incorrectly. The investigator must be honest and faithful, his observations must be accurate, and his records must be complete and contain only information relevant to the problem under consideration. Sometimes graphs, tables, and summaries are valuable in pointing out significant facts concerning the information which was collected. After all pertinent information is accurately recorded the next step follows.

6. Drawing logical conclusions based on scientific analysis and correct interpretation of data and facts obtained

After the information and data are recorded in such ways as to give accurate and meaningful revelations they must be interpreted correctly. This involves checking the hypothesis. If the hypothesis is not proved, it may have been incorrect. However, the hypothesis may have been correct but the collected data may have been inaccurate, incomplete, or incorrectly interpreted. All types of facts are present around us but the accurate collection of those which pertain to our particular problem and the logical interpretation of them are very important in a scientific method. If carefully and accurately utilized, a scientific method is a blueprint from which scientific knowledge is built. Great care must be taken not to draw conclusions which are broader than the collected facts will actually support or warrant. After a conclusion has been drawn the last step follows.

7. Rechecking all steps—hypothesis, data, methods of investigation, erroneous information, and errors in interpretation

After a conclusion is drawn it is highly desirable to recheck each of the steps to reveal errors of omission or commission which may change the final results. If experiments were performed they should be repeated sufficiently and their results compared with those of the original experiments which had been done under identical conditions. The one factor in the control should also be checked to ascertain if there might possibly be another unwanted factor present. We must also search for additional relevant information and data which may have been missed previously. Our final conclusions must be checked against our original conclusions.

NOTE TO THE STUDENT: In your attempts to solve problems in the laboratory or field follow the above steps in a scientific method as closely as possible. Approach each exercise in the manner described, placing the proper statements, hypotheses, methods of investigations, data and information, drawings, conclusions, etc., in proper sequence on blank pages the size of this page. On each page (upper right corner) print your name, section number, and the date. When the exercise is written up completely, each of the steps in correct sequence will have been completely filled in. These steps are listed in briefer form and may not always be described in detail in each exercise, so you shall have to refer to them here until you have memorized them. Attempt to use this technic in solving problems not only in biology but also in as many other fields as possible. Make such a method a habitual pattern to be followed wherever you can.

Use of a scientific method

A SCIENTIFIC METHOD may be used in the solution of many problems in our daily lives as well as those encountered in the laboratory and field. Approach each problem, fact, laboratory or field observation with a curious but open mind so that you may collect information and data accurately and learn the real truth from which to formulate logical conclusions. In order to practice the use of a **scientific method** make the following studies (following the procedures and steps outlined on previous pages).

1. Problem

Is the average height of all male students in your laboratory section greater than the average height of all the female students?

2. Preliminary observations and pertinent data and information

RECORD any preliminary information you may have which might tend to prove or disprove the problem as stated. Do you feel that this information is sufficient to prove or disprove? Where and how can you secure data which may be reliable? Could you trust the information secured from a casual observation of the heights of the two sexes as they all stand in the laboratory? Would this be sufficient and accurate enough to prove or disprove?

3. Formulation of hypothesis and determination of methods of investigation

From your preliminary information formulate a hypothesis regarding this problem. Does this hypothesis actually prove or disprove the problem or must you continue your investigation? RECORD a method of investigation which you feel might give reliable information upon which you might base logical conclusions.

4. Testing correctness (verification) of hypothesis by collection of additional pertinent data

How do you suggest we might get additional, reliable information pertaining to this problem? List actual and accurate procedures to be followed in securing additional and accurate information.

5. Evaluation of collected data and information

How would you propose recording the data secured so that they may give you the information from which you can draw logical conclusions?

6. Drawing logical conclusions based on data and facts obtained

If you measured each of the students, were these measurements made accurately and uniformly? Do you have a sufficient number of individuals of each sex to make your observations valid? Would a ratio of 25 of one sex and 5 of the other sex give reliable data? Why? (Read the problem again.) Does the difference in the heights of heels affect the problem? Do differences in ages of the individuals affect this problem? (Think carefully how the problem is stated.) Does age enter into the solution of this specific problem? Would it be desirable to have the same two students do all the measuring with a system of accurate markings on a wall or door? Should all students be told to stand erect? Does this affect this problem? RECORD and discuss any other pertinent comments on the proper collection and interpretation of the data. What conclusions can you draw from the interpretation of the data as collected and recorded?

7. Rechecking all steps

Have you rechecked all steps carefully? Are your mathematical computations accurate? Do you know of any places where errors might have been made? Check for them.

To give additional practice in the use of a **scientific method** select a problem of your own choice, being careful to choose one for which you are able to get sufficient and reliable data. Follow each of the steps outlined. What are your conclusions and are they justified in the light of the information which you secured?

3

Preliminary microscopic work

1. Problem

Is the microscope composed of various parts, each of which performs a specific function, and as a result is the visual image (as viewed through the ocular, or eye-piece) enlarged and reversed?

2. Preliminary observations and pertinent data and information

RECORD all preliminary information concerning this problem with which you are definitely familiar. Be accurate and do not record facts which are vague and of which you are not absolutely certain.

3. Formulation of hypothesis and determination of methods of investigation

From your limited knowledge would you hypothesize that the problem is correct or incorrect? What method of investigation would you suggest to secure additional reliable information in the solution of this problem? Would the actual and proper use of a microscope assist in gaining some additional information?

4. Testing correctness (verification) of hypothesis by collection of additional pertinent data

Place a microscope on the table directly in front of you with the base about one inch from the edge and with the upright (arm) toward you. **Handle carefully to prevent damage.** Examine and identify such parts as the **base**; the **stage** with its circular opening; the upright, supporting arm; the **substage condenser** just beneath the stage and consisting of a set of lenses (certain microscopes may not have a condenser); the **diaphragm** constructed like a camera shutter just beneath the stage (on some microscopes this part may be a revolving disk with holes of various sizes) for controlling the amount of light; in some microscopes the diaphragm may be an integral part of the condenser, if the latter is present, or it may be present without a condenser; the **mirrors**, one flat (plane) and the other concave; the **objectives** (high and low power) attached to a revolving **nosepiece** (the shorter of the objectives is the lower power); the **ocular (eyepiece)** at the top of the **body tube**; the **coarse adjustment** (usually a pair of larger wheels), and **fine adjustment** (usually a pair of smaller wheels or a single wheel) for focusing (these adjustments vary with the make and model of the microscope).

The microscope is used so extensively that to become efficient with it and to know how to care for it properly the following rules should be memorized and followed carefully.

(a) Before using a microscope see that all parts are in proper working order and report any damages or maladjustments to the instructor at once. Do not take the microscope apart or attempt to make major adjustments yourself because you may do major damage to it.

(b) If the objectives or oculars are soiled **clean with a special lens paper and not with cloths or handkerchiefs. Objects cannot be seen clearly through soiled oculars and objectives.** If they cannot be cleaned easily, report to the instructor.

(c) **Always use low power (shorter**

objective) first and get the object centered exactly before attempting to use high power (longer objective).

(d) Move the mirror until the field as seen through the microscope with low power is uniformly bright and clear. **Never use direct sunlight.** Use the concave mirror to reflect light upon the object from the nearest window or lamp. (Try the plane mirror with this source of light, observing any difference in illumination.)

(e) Adjust the diaphragm to secure the proper intensity of light and visibility.

(f) Never use high power unless the object is covered with a cover glass. Be sure that the cover glass is uppermost on the slide.

(g) **Focus carefully,** first with the coarse adjustment, then with the fine adjustment. **Never focus downward** while looking through the microscope or the objectives and object may be damaged seriously. When focusing, use the coarse adjustment, and while looking at the objective from the side bring the tip of the objective within one-fourth inch of the slide. Then, while looking through the ocular turn the coarse adjustment slowly in order to raise the objective until the object comes into view clearly. Readjust the mirror and diaphragm or move the slide to see the object clearly. To use the high power (longer objective) swing the high-power objective into position (watching from the side so it does not touch the slide). A slight refocusing with the fine adjustment may be necessary.

(h) Learn to keep both eyes open when looking through the microscope to avoid eyestrain. This may seem difficult but with patience it can be mastered.

(i) Use the fine adjustment when looking at the object, turning it forward and backward slightly so that more details will be seen with less eye fatigue. If the fine adjustment comes to the limit of its range do not force it, but turn it in the opposite direction until it is near the middle of its range. Then refocus with the coarse adjustment and make slight turns of the fine adjustment again.

(j) Never expose the microscope to direct sunlight.

(k) The ocular usually carries a number which indicates its magnifying power (such as 10×). A similar number on the objective indicates its magnifying power. The magnification (in diameters) for any combination of ocular and objective is determined by multiplying these numbers. Certain microscopes do not have such numbers; hence the magnifications must be determined from a special chart.

(l) At the close of the period examine the microscope to see that everything is clean and in proper working condition. Be sure to remove the slide, turn the low-power objective into position, turn the slide clips to proper positions on the stage, and return slide and microscope to the proper places.

After you have memorized the rules given above and have learned the names and functions of the parts of the microscope, you need practice for efficiency. As you continue this exercise be alert constantly for any information which may help you to answer the problem stated at the beginning of the exercise. Place a slide containing a letter "L" (or similar preparation) on the stage with the letter in the center of the opening on the stage. Follow the rules for the operation of the microscope carefully and make the following observations: (a) When compared with the letter on the slide, how much is the image enlarged? (b) Is the image reversed? (c) In which direction does the image move when the slide is moved to the right? (d) When moved to the left? (e) When moved away from you? (f) When moved clockwise? (g) When using the same ocular how much greater is the magnification when using the high-power objective than when using the low-power objective?

Place a prepared slide of 3 colored threads (or similar object) on the stage and proceed as previously directed. As you place the slide in position note the sequence of colored threads from below to the upper side of the slide. By using fine adjustment observe the depth of the mount, especially where the threads cross. Make the following observations: (a) As you observe the image are all 3 threads equally clear when the focus is at a certain level? Why? (b) Do the colored threads appear in the same sequence (from bottom to top) when the image is compared with the actual thread arrangements on the slide? What is the explanation for this? (c) At which level are all threads in best focus? Why?

5. Evaluation of collected data and information

Have you secured sufficient information to prove that each part of a microscope performs a certain function? What proof do you have that the image as seen through the ocular is enlarged and reversed when compared with the object on the slide? What evidence do you have that a microscope when in focus at a certain level does not show objects clearly which are above or below that particular level?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from your observations and data? Have you proved or disproved the problem? From your collected information and data can you logically draw any other conclusions? If so, LIST them with the evidence for each. Does the specific magnification depend upon the particular combination of ocular and objective used at any one time? Why does the image move in the opposite direction from the movement of the object on the slide?

7. Rechecking all steps

Can you think of any part of your work where you may have made faulty observations or errors? If so, repeat such observations or procedures a sufficient number of times to ensure correctness. Repeat your use of the microscope with the slides until you are proficient in its operation, because your future progress may depend on this.

4

Early history and development of natural science

Questions

How long ago did man first study plants and animals? Why was man interested in the living organisms with which he associated? What contribution did the guild of root-cutters (Rhizotomi) make? When and by whom were the early foundations of natural science laid? Why was it called natural science rather than biology? Is biology still referred to as a natural science today? Why? What contributions were made by Greeks, Romans, Egyptians, Assyrians, etc.?

What practical uses of plants were made by the Chinese approximately 4,500 years ago? What contributions were made by the early inhabitants of the Americas nearly 5,000 years ago?

What was the extent of the so-called "Dark Ages" and what were the consequences in science? Did early investigators really attempt to solve problems by scientific methods as we know them today? Why? What types of contributions were made by such publications as "Herbals" and "Bestiaries"? What were some characteristics of the scientific activities in Arabia during the years 800—1300 A.D.? What happened to science during the so-called Renaissance period? What contribution was made by Gaspard Bauhin? What effect did the "Doctrine of Signatures" advocated by Paracelsus (1493—1541) have on medical science? Why were earlier investigators called natural philosophers? Is philosophy still used in biology today and, if so, for what purpose?

WRITE A REPORT on the topic "Early History and Development of Natural Science," attempting to answer the questions proposed above and including additional information (from outside reading) so that the subject is covered rather completely. If you secure information from references, be sure to include a bibliography at the end of your paper. This should include the author and title of the reference, date published, publisher, page references, etc.

5

Molecular and cellular biology

1. Problems

Are atoms and molecules present in the constituents of living protoplasm? What are some of the important characteristics of atoms and molecules from structural and activity standpoints, and may some of them help to explain certain phenomena found in living plants and animals? Do atoms and molecules possess energy, and might such energy play a role in living organisms? What is the role of energy in the formation of foods? What happens when foods are digested? Does energy always display itself in the form of visible movement? Are there several different types of energy? Is there one definition which may be applied to all types of energy? Are all plants and animals composed of one or more cells, and how are cells constructed so as to perform the various functions which are necessary for life? Do the cells of animals and plants have certain structures and functions in common? Are there certain differences between plant and animal cells? Do all the cells of a certain tissue possess rather similar characteristics but have rather different characteristics from the cells of a different tissue, even in the same organism?

2. Preliminary observations and pertinent information and data

RECORD all reliable and pertinent information you have which tends to prove or disprove the problems. (Record only that information which you know is accurate.) Is this limited information sufficient to prove or disprove these problems? Why do you say so?

3. Formulation of hypotheses and determination of methods of investigation

From the preliminary information state hypotheses from which you may work toward the solution of the problems. RECORD methods of investigation which may provide additional pertinent information. How can you secure additional information which is relevant to these problems? Are these sources of information reliable and sufficiently extensive to prove or disprove the hypotheses?

4. Testing correctness (verification) of hypotheses by collection of additional pertinent information

MOLECULES AND ATOMS IN LIVING ORGANISMS

Much progress has been made in recent years in securing information concerning the subcellular structures and functions of many living plants and animals. The analysis and interpretation of many phenomena in living organisms have been made possible by recent advances in technics and equipments, including electron microscopy, special staining technics, improved chemical analyses, etc. However, in beginning work many interesting facts can be secured by studies in which ordinary microscopes are used. Since the use of the electron microscope is not practical in beginning courses, it seems desirable to think at least of the molecular and atomic level. The molecular biologist today is vitally interested in the structures and behaviors of the molecules and atoms of which the components of cells are constructed.

Study models, charts, projected lantern slides, illustrations, etc. which demonstrate atoms and molecules, especially those present in the constituents of protoplasm. Learn as much as you can about the structure and behavior of atoms and molecules.

DRAW and label accurately such atoms and molecules as suggested by the instructor.

CELLS AND THE CELL PRINCIPLE

The Cell Principle, formulated by Schleiden and Schwann in 1839, states that all living organisms are composed of cells (and cell products). Consequently, in order to find out if this is true, it is desirable to get first-hand information through studies of representative cells of plants and animals. Time does not permit a detailed study of great numbers of organisms, so a study of cells of an animal and a plant will suffice at the moment. Any additional studies of cells in plants and animals throughout the course will give additional evidence.

Animal cell (Necturus liver)

Examine (low power) a slide containing a stained section of the liver of the amphibian animal known as *Necturus* (or some other satisfactory animal tissue). Read references on this animal, a relative of the frog. Note the shapes, sizes, and arrangements of the cells. The entire liver is composed of cells, and an examination of any part of it will reveal similarities to those you are observing. The cells have been stained with a dye to bring out details because unstained cells are not sufficiently visible.

There are many details in cells which we will not be able to observe with ordinary microscopes, but some of them are given so as to get a more complete idea of their structure. Many of the details have been observed with electron microscopes and phase-contrast microscopes, so you will not be able to distinguish all of them with ordinary microscopes. However, try to identify as many as possible and study each of them, condensing all the information so that you will have a fairly complete knowledge of cells.

Examine (high power) a single cell, noting carefully the following: (1) The **cell (plasma) membrane** is a delicate external boundary of each cell. (2) The **cytoplasmic matrix** or **ground substance**, which fills the space between the cell membrane and the internally located nucleus, is composed of an intricate meshwork of elongated protein molecules and is responsible for many of the cell functions. Within the cytoplasmic matrix the following are located. (a) The **endoplasmic reticulum** is composed of delicate, membranelike, parallel structures with tiny particles of ribonucleic acid (RNA) clinging to their surfaces. These structures supply a greater surface for the placement of the cellular enzymes and provide for the entrance, exit, and circulation of essential substances in connection with the cell. (b) When the reticulum is broken into fragments with their RNA-rich particles they are called **microsomes**, which are especially active in the synthesis of proteins. (c) Numerous rodlike or roundish, noncellular **mitochondria** are surrounded by a thin double layer, with the inner layer folded to form partition-like ridges, plates, or crests which extend inwardly. Mitochondria produce oxidative energy-transfer enzyme systems whereby usable energy is supplied for various cell activities. (d) The **Golgi apparatus** is quite prominent in certain kinds of cells and has a large surface area because of a series of membranous structures of variable size and shape. In some types of cells it appears as a pile of joined, concentric (curved) dark layers rich in fatty materials. It is considered to be a center of cellular synthesis. (e) The **centrosome** is an area of dense protoplasm usually located near the nucleus but is usually rather inconspicuous except during cell division, when it plays an important role. (f) Spherical-shaped **fat globules (droplets)** are found close to mitochondria. The latter break down fats to yield energy and build up fats when more sugar is available than is needed at that time. (g) Small, spherical, liquid-filled **cytoplasmic vacuoles** are scattered in the cytoplasm for storage of various materials and to help maintain the internal pressure in cells. (h) Numerous other structures and materials include granules, foods, wastes, etc. (3) The **nucleus** is usually located near the center of the cell and contains **chromatin materials (genes)** which transmit hereditary traits. Definite structures of chromatin materials, known as **chromosomes,** can be observed in the nucleus only at certain times, while at other times the chromatin may appear as stringlike, granular structures. (4) The **nuclear membrane** which surrounds the nucleus is thin, double-layered, and is supplied with minute, pore-like perforations for the exchange of materials between the nucleus and surrounding cytoplasm. (5) The **nucleolus** ("little nucleus") is present within the nucleus when the cell is not dividing. It is composed of protein and ribonucleic acid (RNA) and is thought to be concerned with metabolism, especially in protein manufacture.

Many detailed structures are present in animal cells but they may not be distinctly visible to the untrained eye. Often the peculiar appearance of a certain structure may be due to the actions of certain chemicals with which the tissue was prepared and stained.

Make an enlarged DRAWING of a *Necturus* liver cell, labeling as many parts as possible. Print the labels neatly and accurately.

Plant cell (Spirogyra, a green alga)

To secure information concerning plant cells study both a prepared, stained slide of *Spirogyra* and a slide of living *Spirogyra* (or similar plant cells). These plants, commonly known as "pond scums," are green algae whose cylinder-shaped cells are attached end to end to form an unbranched, threadlike colony. Place some living *Spirogyra* in a drop of water on a clean slide and cover with a clean cover glass. From your studies of the prepared stained slide and the living *Spirogyra* observe the following facts: (1) The **cell wall** surrounds the cell. (2) The indistinct **cell (plasma) membrane** is present just beneath the cell wall. (3) The oval **nucleus** is suspended in the center of the cell by means of **cytoplasmic strands** which extend from the nucleus to the chloroplast. (4) The **nuclear membrane** separates the nucleus from the surrounding cytoplasm. (5) **Chromatin materials (genes)** are present within the nucleus. (6) The thin layer of **cytoplasm** is just inside the cell membrane and several **cytoplasmic strands** extend toward the nucleus. (7) The large central **cytoplasmic vacuole** occupies much space within the cytoplasm and is filled with water and other materials. (8) One or more spirally coiled, ribbon-shaped **chloroplasts** extend from one end of the cell to the other, forming the basis for the name *Spirogyra* (Gr. *speira,* coil; *gyros,* curved). (9) Numerous starch-forming **pyrenoids** are spaced at intervals on the spiral chloroplast. The chloroplasts contain chlorophyll by means of which foods are photosynthesized from carbon dioxide and water in the presence of energy-supplying light. The filamentous arrangement of cells in *Spirogyra* is due to the fact that the cells divide crosswise (at right angles to their long axis). Some of the details have not been repeated so that they should be reviewed from the discussion for animal cells given previously. Note particularly such differences and variations as cell wall, centrosome, chloroplasts, pyrenoids, the number and sizes of cytoplasmic vacuoles, etc.

Because certain cells of *Spirogyra* may not appear as described above but may contain a large oval body called a **zygote,** it is necessary to describe the method of reproduction known as **conjugation.** Two filaments lie side by side and small projections appear at corresponding points in opposite cells of the two filaments. Eventually a **conjugation tube** is formed when the two projections meet. The so-called **male gamete** formed from the protoplasm of one cell moves through the conjugation tube to fuse with the **so-called**

female gamete which has been formed from the protoplasm of the opposite cell. The union of the two cells forms an oval-shaped **zygote** in one cell, leaving the opposite cell empty. New cells of *Spirogyra* are formed when the zygote germinates, and the filament results from repeated cell divisions.

Add a small amount of iodine solution at the edge of the cover glass of a living *Spirogyra* slide and note carefully any changes that occur. Explain these changes.

If desirable study the cells of additional animals and plants, attempting to identify all structures correctly.

DRAW an enlarged cell of *Spirogyra*, labeling all parts correctly and neatly. (Print all labels.)

Make a TABLE in which you RECORD the information you have collected for animal and plant cells, noting (1) all points of similarity between the two kinds of cells and (2) all differences between the two types of cells.

5. Evaluation of collected information and data

Does the collected information prove or disprove the hypotheses? Do you feel this is sufficient evidence to prove or disprove the problems originally stated? Why? Would studies of additional cells from other animals and plants supply additional proof for or against the hypotheses? Can one get too much reliable information? Would you expect to find all structures identical in the cells of different animals; in the cells of different plants; when animal and plant cells are contrasted?

6. Drawing logical conclusions based on data and facts obtained

LIST the conclusions you have drawn from the information you have secured.

7. Rechecking all steps

Have you secured a sufficient amount of information to justify your conclusions? Why do you say so? Might you have made erroneous observations and interpretations in your studies? If so, how might you rectify such errors? If time does not permit your making additional laboratory studies of animals and plant cells, might you use as proof the results of observations made by many other investigators? Where could you secure such information and would it be reliable?

Physical properties and chemical composition of protoplasm

1. Problem

Does protoplasm possess certain physical properties and chemical constituents which can be ascertained by proper scientific studies?

2. Preliminary observations and pertinent data and information

RECORD all the pertinent and reliable information you have which tends to prove or disprove the problem. (Record only that information which you know is accurate.) Is this limited information sufficient to prove or disprove these problems? Why do you say so?

3. Formulation of hypothesis and determination of methods of investigation

From the preliminary information which you have, state a hypothesis from which you may work in the solution of the problems. RECORD methods of investigation which may provide additional pertinent information. How can you secure additional pertinent information? Are your suggested sources of information reliable and sufficiently extensive to prove or disprove the hypothesis? Would a careful study of living protoplasm in the cells of plants and animals supply such information?

4. Testing correctness (verification) of hypothesis by collection of additional pertinent data

With a clean forceps remove a fresh, young leaf from the tip of a stem of the fresh-water plant known as Elodea *(Anacharis)*. Mount in a drop of water on a clean slide, covering with a clean cover glass. Examine with low power, observing the sizes, shapes, and arrangements of the cells. With high power observe the living protoplasm in several cells, noting carefully (1) the type of movement, (2) the direction of movement in adjacent cells (focus carefully to observe only one cell at a time), (3) the consistency of the protoplasm, (4) its color, (5) the continuity of movement (whether it stops or reverses), (6) any bodies suspended in it (that is, disc-shaped, green chloroplasts for manufacturing food by photosynthesis), and (7) whether the protoplasm or its suspended bodies pass through the cell walls from one cell to another. (Focus carefully.) RECORD all data and observations.

DRAW a cell of Elodea (2 inches long) labeling all parts accurately and neatly.

With a clean medicine dropper carefully remove a drop of water from a culture containing the single-celled protozoan called the *Amoeba*. Place the drop on a clean slide and carefully cover with a clean cover glass. Examine with low and high powers (adjusting the light so that the unstained protoplasm becomes visible). An ameba is a grayish mass of material which may be changing its shape and displaying a flow of protoplasm within the cell. With high power note carefully (1) the type of movement displayed by the protoplasm, (2) its color, (3) the consistency of the protoplasm, (4) the continuity of movement (whether it stops or reverses), (5) any bodies suspended in it (that is, granules, vacuoles, etc.), (6) whether the protoplasm or its suspended bodies pass through the cell membrane, (7) any differences in the protoplasm in various parts of the cell (that is, a clearer layer on the outer margin of the cell). RECORD all data and observations.

DRAW an ameba (2 inches in diameter), labeling all parts accurately and neatly.

Scientific chemical analyses of protoplasm have revealed the presence of such materials as carbohydrates (starches, sugars, etc.), fats, proteins, inorganic (mineral) salts, etc. Time and experience may not permit you to make such analyses but DEMONSTRATIONS of tests for some of these materials may supply information for solving our problem. Before making actual tests on protoplasm it may be well to observe the technics and results of the tests which are commonly employed.

Test for sugar. Place 5 ml. (5 c.c.) of grape sugar (glucose) solution in a test tube and add 5 drops of Benedict's alkaline-copper reagent.* Heat for 5 minutes in a water bath (100° C.). The presence of sugar is indicated by an orange-red precipitate resulting from the reduction of the blue copper (cupric) salts in the reagent to red copper (cuprous) oxide. Observe the color changes against a white background.

Test for starch. Place some starch solution in a test tube and add a small amount of iodine reagent.* The presence of starch is indicated by a blue coloration resulting from the adsorption of iodine to the surface of the starch. Observe color changes against a white background.

*See Appendix 3.

Test for fat. Place a small piece of lard or other fatty or oily material in some water in a test tube and to the mixture add a small amount of an alcoholic solution of the stain, Sudan IV.* The Sudan dyes are very soluble in alcohol, fats, and oils but are less soluble in water. When fats are present the stain concentrates on the fat particles.

Place a small quantity of lard on brown paper and remove the excess. Allow it to dry for several minutes, noting the greasy appearance of the paper.

Test for protein. Place some albumin (protein) such as egg white (fresh or powdered) in some water in a test tube. To the mixture add a small amount of concentrated nitric acid and heat gently. The presence of protein is indicated by a yellow color which may be intensified by adding a small amount of a strong basic substance such as ammonium hydroxide. The yellow color results from the chemical reaction of the acid with certain amino acids which are components of proteins.

CAUTION: Strong acids and bases are dangerous if they come in contact with your body or clothing. In case of accidental contact, flood with water immediately and report to your instructor.

After you have become familiar with the technics and results of the above tests, RECORD on a separate page the results of tests for the presence of sugars, starches, fats, and proteins in such biological products as suggested by the instructor. (Suggested substances may include potato, apple, bean, meat, nut, bread.)

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypothesis and problems? Would additional pertinent data supply more evidence to prove or disprove them? RECORD any instances where you may have secured erroneous information or where you may have interpreted information incorrectly.

*See Appendix 3.

6. Drawing logical conclusions based on data and facts obtained

LIST the conclusions which you can draw logically from the information which you have secured.

7. Rechecking all steps

Recheck all steps which you have followed in your attempt to solve the problems. Recheck any points about which there may be doubt in your mind and repeat any observations where errors may have been made.

Activities of living protoplasm

1. Problem

Does the living protoplasm of various plants and animals possess certain activities which can be ascertained by proper scientific studies?

2. Preliminary observations and pertinent data and information

RECORD all reliable and pertinent information you have which tends to prove or disprove the problem. Is this limited information sufficient to prove or disprove the problem? Why do you say so?

3. Formulation of hypothesis and determination of methods of investigation

From the preliminary information which you have state a hypothesis from which you may work in your attempt to solve the problem. RECORD methods of investigation whereby you may secure additional information which will be reliable and sufficiently extensive to assist in the solution of the problem.

4. Testing correctness (verification) of hypothesis by collection of additional pertinent data

In addition to those activities of living protoplasm which you have studied already there are many others displayed in various plants and animals under a variety of conditions. Some of these which can be demonstrated rather easily include metabolism, growth, movement, irritability, conduction, regeneration, etc.

Metabolism. Metabolism includes the sum total of all chemical transformations which occur in the body of a living organism. Several hours before the laboratory period make a yeast culture.* Allow to stand in a warm place.

Place some of the yeast culture in a fermentation tube (Smith type) so that the closed arm is completely filled and the enlarged bulb is about one-half full. Place in a warm place. As the living yeast cells metabolize a gas is formed, some of which will ascend and displace the liquid in the closed arm. What is this gas and what is its source? What odor do you detect?

Fill a similar fermentation tube with some of the yeast culture which has been boiled sufficiently to kill the living yeast cells. Place in a similar warm place and contrast the results with the first tube. EXPLAIN the results. Does this second tube act as a control?

Place 150 ml. of the yeast culture in a 250 ml. flask and insert a tightly fitting one-hole rubber stopper in which has been placed an L-shaped piece of glass tubing. The latter extends just below the lower surface of the stopper. In a similar flask place 150 ml. of a filtered, saturated, aqueous solution of barium hydroxide* (which has been kept in a tightly stoppered bottle).

*See Appendix 3.

The L-shaped glass tubing in this flask must extend through the stopper and practically to the bottom of the barium hydroxide. Connect the two free ends of the L tubes with a tightly fitting rubber tube. Place the two connected flasks in a warm place. As gas is produced in the yeast flask it will bubble through the barium hydroxide thereby producing a precipitate (barium carbonate). What is this gas? What odor is produced? Does this show metabolic activity by the living yeast cells?

Growth. About 5 days before the laboratory period place a piece of sterile, heavy filter paper in the bottom of a sterile Petri dish. Wet the filter paper with sterile water and place on it several radish seeds. Cover and place in the dark, keeping the filter paper moistened properly. The root hairs will develop in about 5 days.

Several days before the laboratory period place an onion over the opening of a beaker which has been completely filled with water. (The bottom of the onion should touch the water.) Roots will develop downward into the water.

Observe representative stages of growth of such animals as are supplied by the instructor.

Movement. With a scalpel carefully scrape some of the living, ciliated epithelial cells from the roof of the mouth of a frog which has been anesthetized. Mount on a clean slide in a drop of 0.7 per cent salt solution. Cover with a clean cover glass and examine, noting that the hairlike cilia vibrate rapidly. (Focus carefully with the light adjusted properly.) What is the function of such movement?

If desirable a small piece of the gill of a living clam may be mounted in a drop of liquid from the clam and teased apart with clean needles to show similar actions by cilia. What is the function of such movement in the clam?

Anesthetize a frog and wrap it securely on a thin board or piece of flat cork which has a hole near one end. Mount the web of the hind foot over the hole, using small pins to spread the toes. Keep the preparation moist. With a binocular microscope observe the blood flowing in the capillaries. The liquid plasma of the blood carries the blood corpuscles in suspension.

If desirable the blood flow may be observed in the gills of a salamander.

Examine with high power a drop of water containing a suspension of a powdered dye such as carmine. (Focus carefully and adjust the light properly.) Carefully observe whether the dye particles merely oscillate back and forth or actually move from a certain point to another point some distance away. This is known as Brownian movement and must not be confused with the larger movements sometimes set up under the cover glass by the draining of the slide or the pressure of the cover glass. Does Brownian movement differ from that observed in living protoplasm? Does this type of movement suggest that carmine is alive? EXPLAIN the causes of Brownian movement of the nonliving dye particles. DESCRIBE specifically the differences in the movements of living protoplasm and small nonliving particles.

Irritability and conduction. Observe the results when a sensitive plant *(Mimosa)* is stimulated. Even though the plant does not have a nervous system the living protoplasm may be affected by stimuli and display certain reactions. RECORD accurately your answers to the following questions. What happens when the smallest leaflet is touched lightly with a clean needle? What happens when a stem is touched? What happens when a lighted match is brought near the plant? Is this reaction due to heat, light, or to both? What happens when the light from a flashlight is brought near the plant? What does this prove? Do the effects of stimulating one small part of the plant seem to affect other parts which were not directly stimulated? What characteristic of living protoplasm does this phenomenon illustrate? What is the effect when a small drop of alcohol is applied (without touching the plant with the dropper)? Is this due to the chemical stimulation by the alcohol, the mechanical action of the drop of a foreign material, or a combination of the two? Repeat the above with a small drop of distilled water. What do you conclude? Observe the previously stimulated plant after it has rested for some time. What specific characteristic of living protoplasm does this illustrate?

Using a pithed* frog cut the skin around the base of the thigh and remove the skin from the hind leg. Find the two large muscles on the dorsal side of the thigh and the whitish, cordlike sciatic nerve between them. Carefully separate the nerve from adjacent tissues and trace it to the large spindle-shaped gastrocnemius muscle located on the inner surface of the shank (lower leg). What happens when the sciatic nerve is touched by a clean needle? What happens when you pinch it with a clean forceps? Stimulate the nerve with an electric current from a dry cell battery. What happens when you cut the nerve with a clean scissors? After the nerve is cut do similar stimulations of it still result in muscular contractions? What specific phenomena of living protoplasm are illustrated by the nerve and muscle?

Regeneration. Regeneration is the inherent ability of certain living organisms to replace certain parts which may have been lost or injured. Place a living planarian flatworm *(Dugesia)* on a clean slide in a drop of pond water. When expanded, cut the worm with a clean square cover glass at the desired point. Cuts may be made crosswise at various places along the long axis or lengthwise, such as splitting the anterior (head) region. Allow the cut pieces to regenerate in clean watch glasses containing pond water. Cover and store in a dark, cool place, changing the pond water every day. Label each watch glass showing the portion of the worm contained. Observe at intervals to note the stages in the regenerative process. RECORD the results noting the time interval since the animal was cut.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypothesis and problem? Would additional pertinent information supply more evidence to prove or disprove them? EXPLAIN any instances where you may have secured erroneous information or where you may have interpreted information incorrectly. Can you think of places where the experiments may have been faulty? Why do you say so?

6. Drawing logical conclusions based on data and facts obtained

LIST the conclusions which you can draw logically from the information which you have secured. Do they prove or disprove the problem as stated?

7. Rechecking all steps

Recheck all steps in your attempt to prove or disprove the problem, especially where you think errors may have been made. Would it seem desirable to repeat the experiments or observations? Why do you say so?

*The brain of a frog may be pithed by pressing the head down so that it makes a right angle with the body. With your finger locate the depression between the skull and the first vertebra. With a sharp scissors cut the skin at this point. Push a blunt needle through the overlying muscles into the brain case (toward the tip of the head). Twist the needle from side to side until the brain is destroyed.

Part Two

PLANT BIOLOGY

8

The plant kingdom—major groups of plants

1. Problems

Do the thousands of kinds of plants possess traits whereby they may be classified in the form of a key? By the accurate use of a proper key and the correct interpretation of certain traits of an unknown plant is it possible to identify such an unknown plant?

2. Preliminary observations and pertinent data and information

RECORD all reliable information which you may have at this time which tends to prove or disprove these problems. Be accurate in your statements.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable preliminary information which you possess state hypotheses from which you may work in your attempts to solve the problems. Be accurate and specific in the formulation of these hypotheses. State methods of investigation which would supply additional information which will be reliable and sufficiently extensive to assist in the solution of the problems.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study, very carefully, labeled specimens of algae, fungi, thalloid liverworts, leafy liverworts, true mosses, club "mosses," horsetails, ferns, gymnospermous plants, and angiospermous (flowering) plants, as supplied by the instructor. By referring to the proper places in the accompanying Simple Key for Classifying the Major Groups of Plants, observe carefully all the traits listed which characterize each major group. Be sure you are familiar with each detailed trait because you will be required to identify unknown plants by the correct interpretation of these detailed traits. In a few places you may need some assistance from the instructor concerning certain points.

How to use a key. Quite naturally space does not permit the presentation of a complete and detailed key, but this simple one will give you practice in the use of more detailed keys later. In the use of this key start with A. If the description given there applies to the specimen you are studying, then you have started to find out the group to which your specimen belongs. NOTE: Always check the opposite or alternative traits (in this case those under AA) to ascertain if the traits described there might fit your specimen. If the traits under A apply, then proceed to B or BB and to each successive category which follows. Continue this procedure until you have traced your specimen down to the proper major group of plants. After you have ascertained the group to which you think your specimen belongs go through the entire procedure again (several times) until you are certain that you are correct in your interpretations. Any error made will end in your failure to correctly identify your specimen. Learn to

SIMPLE KEY FOR CLASSIFYING THE MAJOR GROUPS OF PLANTS*

A—Plants without true leaves, stems, or roots, since no true conducting (vascular) tissues; without rigid upright supporting tissues, hence little upright growth

- **B**—Usually rather small, simple plants, one-celled or many-celled (either linear series of cells or sheetlike mass of cells); no many-celled embryo formed within one-celled female sex structure
  - **C**—With chlorophyll (to carry on photosynthesis); other pigments such as blue, brown, or red may mask chlorophyll . . . . . **Algae**
  - **CC**—Without chlorophyll; other pigments such as black, brown, red, or even green sometimes present . . . . **Fungi**
- **BB**—Relatively small, land plants (usually less than 9 inches high); bodies composed of blocks of many cells; chlorophyll present in special bodies called plastids; alternation of generations between a gametophyte stage (gamete- or sex cell-producing) and a sporophyte stage (spore-producing); many-celled embryo formed within female sex organ; small sporophyte parasitic on female gametophyte
  - **C**—Flat, prostrate plants with upper and lower surfaces different (dorsiventral); many-celled sex organs formed, sometimes at tip of slender upright stalks . . . . **Liverworts (Thalloid)**
  - **CC**—Prostrate plants with short stemlike axis which bears leaflike structures . . . . **Liverworts (Leafy)**
  - **CCC**—Short, erect stemlike axis with small leaflike structures; spore cases at tip of stalk (at certain stages in life cycle) . . . . **Mosses (True)**

AA—Plants with true leaves, stems, and roots; with true conducting (vascular) tissues known as phloem and xylem; rigid supporting tissues, hence upright growth; usually rather conspicuous land plants with chlorophyll in plastids; bodies composed of blocks of many cells; alternation between gamete-producing generation and spore-producing generation; mature sporophyte independent and larger than gametophyte; many-celled embryo formed in female sex organ

- **B**—Do not produce seeds
  - **C**—Leaves small and usually spirally arranged; true stems and roots frequently branched; trailing plants whose creeping stems give off upright stems with small leaves; spore cases usually grouped into clublike or conelike structure (often at tips of stems) . . . **Club "Mosses"**
  - **CC**—Leaves small and attached in whorls at joints (nodes) of hollow stem, which is usually ribbed; spore cases grouped into conelike structures (strobili) at tips of certain stems . . . . . **Horsetails**
  - **CCC**—Leaves (fronds) usually large, divided (compound), and bearing spore cases on under surface; leaves tend to unroll ("fiddlehead") as they continue to grow at their tips for long periods of time; usually horizontal, underground stem (rhizome) . . **Ferns**
- **BB**—Plant produces seeds
  - **C**—Seeds not enclosed in fruit (exposed, naked seeds) but usually borne on scales of seed-bearing cones; leaves simple, small, needlelike, or scalelike; mostly woody, evergreen trees or shrubs . . . . **Gymnosperms**
  - **CC**—Seeds enclosed in fruit (carpel, ovary); flowers produced (sometimes inconspicuous in certain plants such as grasses, etc.) . . **Angiosperms**

*A more detailed classification key is given in Appendix 1.

do things accurately. This may take time, but accuracy pays big dividends on your investment of time and energy.

In order to become more familiar with the use of the key attempt to identify a number of unknown plants which will be supplied by the instructor. Identify these by numbers, giving the proper group of plant to which you believe each plant belongs. Give the group name and RECORD the number of each unknown correctly.

5. Evaluation of collected data and information

Do the collected information and data prove or disprove the hypotheses and problems? Do you feel that your information and studies are sufficiently extensive to form a basis for proving or disproving them? EXPLAIN any instances where you may have made erroneous interpretations including any explanations why you believe you may have done so. Can such a simple key be easily followed in the complete identification of all unknowns? Would a longer, more detailed key be of greater value? In order to emphasize simplicity in a key must we sacrifice detailed considerations which might be more helpful in an easier and more accurate system of identification? Do you feel satisfied that you did an accurate job of identifying all of the plant unknowns? In which groups did you seem to have greatest difficulty? Can you give any logical reasons for this?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the information which you secured? Do these conclusions prove or disprove your hypotheses and problems? If not, what might you suggest in order to do so?

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure information for the solution of the problems. Recheck particularly those points which you believe may have resulted in errors. How many times did you attempt to identify each plant unknown? Was this number of attempts sufficient? Why do you say so?

Cellular organization of plants (tissues and organs)

1. Problems

Are all plants composed of one or more cells, and in higher plants how are these cells organized into tissues and organs? Are there special types of plant tissues, each with its special kind of construction and functions?

2. Preliminary observations and pertinent data and information

RECORD all the accurate preliminary information which you may have concerning these problems. Be sure your information is pertinent and accurate.

3. Formulation of hypotheses and determination of methods of investigation

From your preliminary information state hypotheses from which you may work toward the solution of these problems. Are these hypotheses plausible in the light of your limited information? What methods of investigations do you propose whereby you may be able to secure additional information and data from which you may prove or disprove the hypotheses?

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Would the study of numerous, representative plant tissues give additional, pertinent information? How many tissues should be studied in order to secure a sufficiently extensive amount of information? In general are all plant tissues constructed in a similar way? In order to secure additional data make a careful study of the following tissues (or similar ones as may be suggested by the instructor). Check the characteristics and make labeled DRAWINGS of each tissue.

I. Permanent tissues
   A. Simple tissues
      1. Epidermis—surface of leaves (fresh material or prepared slide)
      2. Parenchyma—pith of a corn stem (prepared slide)
      3. Sclerenchyma
         (a) Fibers—celery, plantain, corn stem, etc. (fresh materials or prepared slides)
         (b) Sclereids—hulls of nuts, gritty masses of pears (fresh materials or prepared slides)
   B. Complex tissues
      1. Xylem
         (a) Tracheids—stem of pine tree (prepared slide)
         (b) Vessels—corn stem (prepared slide)
      2. Phloem
         (a) Sieve tubes—corn stem (prepared slide)
         (b) Phloem parenchyma—corn stem (prepared slide)
II. Temporary tissues
   A. Meristematic tissues—root tips of onion, *Tradescantia*, etc. (prepared slide)

Epidermis. Usually one cell thick, colorless, but such pigments as blue, red, or purple may be present; contain stomata (pores) surrounded by guard cells; cell walls may contain a waxy, waterproof cutin; found on the surface of leaves, flower parts, younger stems and roots; serve as protection, to conserve moisture and exchange gases, etc.

Parenchyma. Cells usually ovoid or spherical (sometimes cylindroid) and with a large central vacuole; cell wall thin; usually numerous intercellular spaces; abundant in higher plants for storage of foods and water.

Sclerenchyma. Cell walls greatly thickened with cellulose and lignin for rigidity and strength; two types: (1) **fibers** which are tough, strong, elongated cells with tapering ends as in the stem of corn; (2) **sclereids ("stone cells")** in which the cells are not elongated but with thick walls as in the hulls of nuts and the gritty masses in pears, etc.

Xylem. Composed of (1) **tracheids** which are elongated, tapering cells whose walls are strengthened and thickened by spirals or rings of lignocellulose and often with pits (thin areas); common in gymnospermous plants such as pine; (2) **vessels** which are long, rather large tubular structures (made of a series of cells) and whose walls may be thickened and with pits; give strength and conduct water and other materials upward through the stems of angiospermous plants.

Phloem. Composed of (1) **sieve tubes** which are elongated rows of cylindrical cells whose end walls contain **sieve plates** with numerous sievelike pores; (2) **phloem parenchyma** whose cells have characteristics previously described under parenchyma and which store foods. Phloem tissues give strength and conduct mainly foods downward through stems and roots.

Meristematic. Cells are small, thin-walled, usually cubical, and usually multiply by cell division; cells closely arranged without intercellular spaces; located primarily in areas where extensive growth occurs, as in root tips, buds, between the bark and wood of trees, etc.; newly formed cells may become differentiated into mature permanent tissues.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Is your collected information sufficiently extensive to prove or disprove? Why do you say so? Did you make accurate observations and did each tissue which you studied have the characteristics described for it? Of the tissues studied did you find any which did not quite fit the characteristics as described? Might this be due (1) to variations of these tissues from the typical, or (2) to errors in your interpretations? Although you did not study all of the various types of plant tissues do you think a study of representative types of all kinds would give additional pertinent information? If you made errors, where were they made and why did you make them? Did you repeat your observations sufficiently to be accurate?

6. Drawing logical conclusions based on data and facts obtained

What logical conclusions can you draw from the information which you secured? Do your conclusions prove or disprove the hypotheses and problems? If not, what suggestions can you make in order to do so?

7. Rechecking all steps

Did you check all observations carefully several times? If not, do so and reconsider your conclusions. Check particularly where you may have made errors in observations or interpretations.

Mitotic cell division (mitosis) in plants

1. Problems

Do plant cells undergo a rather complex process whereby a cell divides to form two new cells, and as a consequence may such phenomena as growth, development, repair, transmission of hereditary traits, etc. take place?

2. Preliminary observations and pertinent data and information

Do you have any preliminary information which is accurate and which pertains specifically to the proving or disproving of the problems? If so, RECORD it accurately.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable preliminary information can you formulate hypotheses from which you may work in the solution of the problems? How might additional pertinent information be secured? (Be specific in your suggested methods of investigation.)

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study prepared slides of the root of onion *(Allium)* or spiderwort *(Tradescantia)* or similar tissue, as suggested by the instructor. Carefully identify each characteristic described under each stage and make correctly labeled DRAWINGS of each. Make each drawing large enough to show details.

As you study the characteristics of each stage move the slide until you find a typical example of that stage. Attempt to identify all parts of the cell in each of the stages. Do this work carefully and accurately. Do you find some cells which do not quite fit the descriptions given? Are all of the stages described, or may some of the intermediate steps have been omitted for the sake of brevity? If any structures are not visible, what explanations do you have for this? Why do we study stained sections of incomplete cells? What significance might this play in explaining the absence of certain structures in some cells as they are observed? Do the various phases (stages) follow one another in a continuous series? Is the separation of the process into phases merely for study purposes?

Interphase. This stage occurs before the phases of actual division begin and in which the **chromatin** within the **nucleus** appears as an irregular network of **intertwining strands** which stain well.

Prophase. Nuclear chromatin begins to form a number of elongated bodies called **chromosomes.** A **mitotic spindle** begins to form at opposite poles of the nucleus. From each pole a cluster of fiberlike structures extend inwardly toward the center of the nucleus. As the **nuclear membrane disappears** these fiberlike spindle structures extend from one pole to the other. Each chromosome seems to be composed of two longitudinal halves known as **chromatids.**

Metaphase. Each chromosome is now somewhat thickened and arranged in the central **equatorial plate region** of the spindle midway between the two poles. Each chromatid now possesses a slender outgrowth called a "tractile fiber." The fiber from one chromatid of each chromosome extends toward one spindle pole, while the fiber from the other chromatid of the same chromosome extends toward the opposite spindle pole. Each fiber is attached to its chromatid at a specific point called a **centromere (kinetochore).**

Anaphase. The chromosome halves (chromatids) separate from each other, one **new chromosome** of each pair moving toward one spindle pole and the other chromosome moving toward the opposite pole. The equal longitudinal splitting of each original chromosome is necessary because the **genes** (carriers of hereditary materials) are arranged in a lineal series along each chromosome. Toward the end of the anaphase the tractile fibers disappear and one group of chromosomes is present at each pole.

Telophase. The chromosomes at each pole become organized into new **daughter nuclei** with the chromosomes intertwining again. A **nuclear membrane re-forms** and the nuclei enlarge. The **nucleolus** which had disappeared is re-formed. The spindle widens greatly at the equatorial plate region until it extends nearly across the cytoplasm. As this spindle widens some thickenings appear on the fibers. The thickenings enlarge and finally fuse to form a continuous **cell plate** across the cell, thus separating the cell into 2 parts. **New cell walls** are formed on either side of the cell plate. The cell as a whole now enlarges to typical size. This stage is followed by the interphase stage again.

Can you give any explanations for such phenomena as growth, repair, development, the transmission of hereditary traits, etc., as a result of your studies? Could the various phases actually be observed in living tissues? What would be some of the difficulties encountered? When such tissues are killed quickly and are then properly sectioned and stained, do we find on such a slide different cells in various stages of division? Do observations on dead cells actually show what living cells might be undergoing in the process? Why do you say so? Do you think that cells in other plant tissues would show stages similar (in a general way) to those which you studied? Do certain cells undergo a division process in all plant tissues at all times? How are old cells replaced in all tissues? Why do we select rapidly growing tissues for studies of cell division?

5. Evaluation of collected data and information

Does the information which you collected prove or disprove the hypotheses and problems? Would it be desirable to study the division of cells in additional plants? Why? Do you think that all plant cells follow much the same general pattern when they divide?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the information which you secured? Do these conclusions prove or disprove the hypotheses and problems? List ways in which additional pertinent information might be secured.

7. Rechecking all steps

Recheck everything which you did in this exercise, especially in places where you may have made errors in observation or interpretation. If you are not sure that you saw certain structures clearly, study the slide again and attempt to clarify those points.

Meiotic cell division (meiosis) in plants

1. Problems

Because vegetative cells of higher plants possess a diploid or double (2N) number of chromosomes, why do two such plants when they cross not have a quadruple number of chromosomes the next generation and successive doubling in all future generations? How and when does the reduction of chromosomes occur before two such plants cross? Does this process of reduction, known as meiosis, follow the same stages (prophase, metaphase, anaphase, and telophase) as does mitotic cell division (mitosis)? What are the chief differences between meiosis and mitosis? If reduction division occurs previous to spore formation, might it be desirable to study spore-producing organs of certain plants at the proper time in order to demonstrate this phenomenon? Of what significance is reduction division in heredity? How is the formation of nonfertilizable cells of significance in heredity? Of what significance is the process of synapsis, in which homologous pairs of chromosomes (homologues) lie side by side and may have a mutual exchange of genic materials? Might this mutual crossover of parts of homologues (and their genes) during synapsis affect heredity? Tell how this might happen specifically.

2. Preliminary observations and pertinent information and data

RECORD any reliable information which pertains to the problems and which may tend to prove or disprove them. Include only accurate, pertinent information.

3. Formulation of hypotheses and determination of methods of investigation

From the preliminary information which pertains to the problems state hypotheses from which you may work toward the solution of the problems. RECORD them as well as specific methods of investigation which will supply additional pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent information

Meiosis consists essentially of 2 nuclear divisions whereas the chromosomes divide only once, eventually forming 4 cells whose nuclei contain the monoploid (haploid) number of chromosomes. These 2 divisions are called the **first meiotic division** (Division I) and the **second meiotic division** (Division II).

Meiosis is essentially the same in fungi, flowering plants, insects, and man. Except for the kind of cell resulting from the process of meiosis, the phenomenon is similar in both sexes, following the same phases or stages in each, namely, prophase, metaphase, anaphase, and telophase. Also these phases of meiosis follow a sequence similar to those in mitosis. When spores are produced in higher plants (and gametes in higher animals), there must have been a previous reduction in the number of chromosomes and their genes from the diploid (2N) to the monoploid (N) number. This reduction in chromosome number is called meiosis, which as stated is really **two nuclear divisions accompanied by only one division of chromosomes.**

Study prepared slides showing the development of the megasporophyte in the embryo sac (female gametophyte) in the anther of the lily (or similar plant). Study each of the following stages with great care and DRAW each one with all parts labeled correctly. Be sure to draw the stages in correct sequence as they actually occur.

STAGES (PHASES) OF MEIOSIS

Prophase I. Meiosis is initiated in this stage and the **meiotic cells and their nuclei are generally enlarged. The paired chromosomes (2N) are relatively long and thin.** They may appear to be single rather than double, and dense **granular chromomeres** (Gr. *chroma,* color; *meros,* part) occur at intervals along their length. The chromomeres are characteristic in size, number, and position on the chromosomes. It is estimated that there may be about 2,000 chromomeres in the entire set of 24 chromosomes of the garden lily.

The **chromosomes** move apparently as a result of attraction forces which bring the pairs of homologous chromosomes (homologues) together. The active pairing, called **synapsis** (Gr. *synapsis,* union), begins at one or more points along the length of the homologues and eventually unites them along their entire length. They may even twist around each other. The chromomeres of one homologue synapse exactly with the corresponding chromomeres in the other homologue. After synapsis is complete the nucleus appears as if only a monoploid number of chromosomes is present, but each is duplicated (paired). The pairs are referred to as **bivalents** (L. ***bis,*** twice; ***valere,*** to be strong). This duplication is due to a longitudinal splitting (division) of each chromosome (except at its centromere region), and the **paired chromosomes of each bivalent becomes shorter and thicker.** The shape of the chromosome is determined by a constriction at a point where the two "arms" of a chromosome meet. Within the constriction is a clear zone, the **centromere, or kinetochore** (Gr. *kinein,* to move; *choros,* place) which seems to be related functionally to chromosomal movements. The **nucleolus attached to a particular chromosome** may be observed with high magnification.

The **homologues tend to separate** from each other because the attraction forces of synapsis decrease. However, complete separation of homologues does not occur at this time. At one or several points along their length homologues may remain in contact by means of **chiasmata, singular chiasma** (Gr. *chiasma,* cross). Each **chiasma results from an exchange of chromatids** (component parts of a chromosome) between two homologues, which may be of great hereditary significance. Each chromosome consists of 2 chromatids (half chromosomes), and thus the bivalents consist of 4 chromatids and may be called collectively a **tetrad** (Gr. *tetra,* four).

When only one chiasma is formed the bivalent may appear as a **cross;** when two chiasmata are formed the bivalent is usually **ring-shaped;** when three or more are formed the homologues appear as **loops.** In general the longer the chromosome the more chiasmata.

The **nucleolus eventually detaches from its particular bivalent and disappears.** The **bivalents contract and the chiasmata lose their original positions.** The **chromosomes tend to shorten** through Prophase I by forming a **series of coils** which decrease in number as the chromosome diameters increase. The **loss of the nuclear membrane** and the **formation of the spindle** terminate Prophase I of meiosis.

Metaphase I. The **bivalents arrange themselves on the spindle,** each member of the bivalent locating itself so that the **centromere of each lies on either side of and equidistant from the equatorial plane.**

Anaphase I. The **paired double chromosomes separate** from one another and **move along the spindle toward the 2 opposite poles.** The **centromeres of each bivalent are undivided** as they and their chromosomes move along the spindle. Otherwise the homologues are freed. Hence a monoploid number of chromosomes will be located at each pole. Each chromosome now consists of 2 chromatids united only at their centromeres. The separation of homologues is called reduction division (meiosis).

Telophase I. The **chromosomes uncoil,** the **nucleus forms,** and the **meiotic cell is divided by a newly formed cell membrane or wall.**

Prophase II. After Telophase I there may be a long or short interphase or none at all, depending on the species. The chromosomes in each of the 2 monoploid cells enter the **second meiotic division.** If there is no interphase, the chromosomes pass unchanged from Telophase I to Prophase II. If an interphase occurs a nuclear membrane forms in Telophase I, the chromosomes uncoil, and a rather long Prophase II results. Regardless of the presence or absence of interphase the **chromosomes are unchanged and no reproduction of chromosomes occurs during interphase, and each centromere now duplicates itself (divides).** A new **spindle forms in each of the 2 cells and at right angles to the axis of the spindle of meiosis I.**

Metaphase II. The **monoploid number of double chromosomes lines up on the equatorial plane of the second spindle.**

Anaphase II. The **double chromosomes divide and the resulting monoploid set of single chromosomes (chromatids) with their divided centromeres moves along the spindle** toward opposite poles.

Telophase II. The **chromosomes become thinner and longer;** the **nuclear membrane forms** and the **cytoplasm divides,** forming 2 cells. Hence the original cell with its diploid number of chromosomes results (after 2 meiotic cell divisions) in the formation of 4 cells, each with its monoploid number of chromosomes (only one of each kind of chromosome). Thus the resulting cells are produced with the reduced number of chromosomes.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Why do you say so? Were your studies sufficiently extensive and representative to prove or disprove them? Explain instances where you may have made errors in observations or interpretations, including reasons why you may have done so.

6. Drawing logical conclusions based on data and information obtained

What conclusions can you draw from the logical interpretation of the collected information? Do these conclusions prove or disprove your hypotheses and problems? Draw additional conclusions which may not be directly associated with the specific problems as stated. Do not draw conclusions which are not justified by the collected information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed, especially those where you may have made errors. Repeat any which you think were erroneous. Do the above repeated observations and interpretations change your original conclusions?

Simple plants with chlorophyll—algae

1. Problems

How are algae, which are single-celled or simple multicellular chlorophyll-bearing plants, constructed so as to perform all of the functions necessary for living? Can algae be divided into several groups (phyla) because they differ from one another in certain structures and functions? How can algae perform all of the functions necessary for living, even though they do not possess true leaves, stems, or roots? How can algae reproduce if they do not possess flowers or seeds?

2. Preliminary observations and pertinent data and information

RECORD any reliable, pertinent information which you may have that tends to prove or disprove the above problems. Include only accurate information of which you are certain.

3. Formulation of hypotheses and determination of methods of investigation

From such reliable, pertinent information which you may possess state hypotheses from which you may work in your attempts to solve the problems. Be accurate and specific in the statements of your hypotheses. RECORD methods of investigation which will supply additional, reliable information that will be sufficiently extensive to assist in the solution of the problems.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

BLUE-GREEN ALGAE (PHYLUM CYANOPHYTA)

These algae are simple, unicellular plants, some species of which form colonies of similar cells. Chlorophyll is diffused in the cytoplasm (not in specialized plastids). A blue pigment, called phycocyanin, is also present. No definitely organized nucleus is present. Cells are often surrounded by a slimy, gelatinous sheath. Reproduction occurs asexually by fission (cell division). None of the vegetative (body) cells or reproductive cells bear thread-like flagella in contrast to many other types of algae.

Study preserved materials, living specimens, and prepared slides of such representative types as suggested by the instructor. Make careful observations and enlarged, properly labeled DRAWINGS of each.

Gleocapsa. Observe the outer bluish-green region due to the diffused **chlorophyll** and **phycocyanin** and a central region containing scattered **chromatin granules.** Note that several individual cells are associated together and surrounded by a jellylike **sheath.**

Oscillatoria. Observe the independent cells (plants) associated in a filamentous colony. Pigments and chromatin are located somewhat as in *Gleocapsa.* Sometimes living filaments swing back and forth (oscillate), hence the name *Oscillatoria.* Soft **gelatinous areas** may develop between cells, thus breaking the filament into pieces called **hormogonia.** The latter may form a new colony.

Nostoc. Observe the chainlike colony of individual, **spherical cells** all enclosed in a **jellylike ball.** At intervals there may be thick-walled, transparent cells called **heterocysts** which serve to break the filaments into **hormogonia,** as in *Oscillatoria.* At times the heterocyst may germinate to form a new filament, thus functioning as a **spore.**

EUGLENOIDS (PHYLUM EUGLENOPHYTA)

Euglena. Euglena viridis is a spindle-shaped organism about 100 microns (1/250 of an inch) long and has a large, centrally located **nucleus.** An anterior **flagellum** propels it through the water in a spiral, rotary manner. It may also move by a twisting of the body ("euglenoid movement"). Numerous small, green **chloroplasts** carry on **photosynthesis. Paramylum granules** (starchlike substance) and fats are scattered throughout the **cytoplasm. Pyrenoids** may be present in some instances, assisting in food production.

At the anterior end is a tubular **gullet** which probably does not ingest solid foods. Near the gullet is a light-sensitive, red **eyespot** and a **contractile vacuole.** Reproduction occurs by dividing the cell lengthwise by **longitudinal fission.** A thick-walled resistant **cyst** may form around the cell during adverse conditions. A few species of *Euglena* lack chlorophyll and these are probably saprophytes, absorbing materials by diffusion through the cell surface.

Euglena and its related forms are considered by some botanists as algae, while some zoologists consider them as single-celled protozoans because of the presence of a tubular gullet (pharynx) and a reservoir through which solid foods may be ingested.

Study a prepared, stained slide of *Euglena.* With a clean pipette place a drop of a culture of living *Euglena* on a clean slide and apply a clean cover slip. Observe and DRAW, labeling all parts correctly.

GREEN ALGAE (PHYLUM CHLOROPHYTA)

Green algae may be unicellular, colonial, or multicellular, depending on the species. Chlorophyll is localized in bodies called plastids (more specifically called chloroplasts). Orange-reddish pigments, called carotenoids, may be present in some species. The nucleus is well organized. Stored food is starch which is formed by special structures known as pyrenoids and associated with the chloroplasts. When vegetative (body) cells or reproductive cells are motile each bears 2 to 8 anterior flagella, usually of equal length. Reproduction occurs (1) asexually by fission, by fragmentation, by motile spores, or by nonmotile spores or (2) sexually by isogamy (fusion of equal sex cells), by heterogamy (sex cells of unequal size), or by oogamy (sex cells of unequal size and the egg is nonmotile).

Study preserved materials, living specimens, and prepared slides of such representative types as suggested by the instructor. Make careful observations and properly labeled DRAWINGS of each.

Chlamydomonas. Each ovoid plant contains one **cup-shaped chloroplast** with a **pyrenoid.** Observe the pigmented **eyespot,** 2 excretory **contractile vacuoles** near the anterior end, and **2 anterior flagella of equal length.**

At times there are formed within the cell, 2, 4, or 8 **motile spores** (zoospores or swarm spores) which look like miniature parent cells and which swim out to form a new generation of *Chlamydomonas.* In some instances the contents of the parent cell may divide into 8, 16, or 32 **gametes** (sex cells) which are also like miniature *Chlamydomonas* plants. In the water 2 gametes of equal size but from different plant cells unite by **isogamy** to form a single-celled **zygote** which is surrounded by a thick, **resistant wall** to withstand adverse conditions. The single nucleus of the zygote forms 4 nuclei which are placed into **4 zoospores,** each of which forms a *Chlamydomonas* plant. The zoospores look much like the gametes, except that the former are larger.

Protococcus. This unicellular, thick-walled green alga is common on trees and in other moist places. Observe the single **nucleus** and a **chloroplast.** Reproduction occurs by **fission** (cell division) and several individuals may form a colony.

Spirogyra. This unbranched, filamentous green alga is composed of a linear series of cells covered with a mucilaginous **sheath.** One or more spiral **chloroplasts** may be present in each cell depending on the species. An organized **nucleus** near the center of the cell is surrounded by a layer of **cytoplasm. Strands of cytoplasm** also extend to the chloroplasts from a layer of **cytoplasm which is just beneath the cell wall.**

Reproduction occurs asexually by **fragmentation** or by **cell division** and sexually by **conjugation.** In the latter the cells of two adjacent filaments form a **conjugation tube** between them and the content of one cell passes through the tube to the cell of the other filament. This union forms a resistant **zygospore** from which a new filament develops. Even though the **gametes** are of equal size (**isogamous**) the one which migrates may be considered the male and the other the female.

Ulothrix. This filamentous, multicellular green alga has a basal **holdfast** for attachment. Each vegetative cell has an organized **nucleus** and a **chloroplast** which resembles an open band or ring and which contains several **pyrenoids.**

Several reproductive structures, called **zoosporangia,** produce 2 to 32 large, **motile zoospores** each with **4 flagella.** Each zoospore forms a new filament by cell division. Other unicellular reproductive structures called **gametangia** produce 8 to 64 **gametes,** each with **2 flagella** and smaller than the zoospores. The gametes arise from different filaments (heterothalli). The union of **isogametes** produces a single-celled **zygote** which produces **4 zoospores** each of which forms a new **filament** by cell division. Asexual reproduction may also occur by fragmentation.

Desmids. These beautiful green algae are common in fresh water and may be unicellular, in filaments, or in irregular colonies (depending on the species). In most species each cell is divided into **2 halves** which are joined by a connecting **isthmus** containing a **nucleus.** Each half-cell contains a **chloroplast.** Reproduction occurs by **cell division** and by **conjugation** (similar to *Spirogyra*).

Volvox. This **fresh-water, flagellated** green alga is a spherical **colony** (1 to 2 **mm. in diameter**) composed of **hundreds** of individuals (cells) embedded in a jelly-like mass and joined together by **protoplasmic strands.** Most of the **body (somatic, vegetative) cells** are for **photosynthesizing food.** Each body cell bears **2 flagella,** chlorophyll in **chloroplasts,** and a light-sensitive **eyespot** (stigma).

In a mature colony there may also be **reproductive (germ) cells** of three kinds: macrogametes (eggs), microgametes (sperms), and parthenogonidia. Some of the large, nonflagellated cells enlarge and each produces a large **egg (macrogamete).** Other cells form **sperm bundles** consisting of many spindle-shaped, biflagellated **sperms (microgametes)** which fertilize the egg to form a thick-walled **zygospore** from which a new colony develops. Still other cells, called **parthenogonidia,** enlarge, divide repeatedly, and produce a new colony by **parthenogenesis** (without fertilization).

DRAW a *Volvox* colony (enlarged) showing all parts labeled correctly.

Volvocine series of green algae. The so-called **volvocine line** of certain green algae shows a **progressive development in cell number increase,** in **sex differentiation,** and a **distinction between somatic (body) cells and reproductive (germ) cells.** It is thought that the ancestral motile, green cells from which many of the more advanced types may have arisen were much like *Chlamydomonas.* When the series is studied, it will be noted that there is a trend from **motile, unicellular types to smaller colonies,** then to **larger colonies in which some of the cells are vegetative and some are reproductive.** Also to be noted is the **origin and progressive development of sexual reproduction** from **isogamy** (similar reproductive cells) to **heterogamy** (unlike reproductive cells).

Study as many of the algae listed in Table 1 as suggested by the instructor and make such DRAWINGS as desired to show the principles involved.

Table 1. Volvocine series of green algae

Alga	Number of cells	Form of colony	Nonreproductive (somatic) cells	Gametes (sex cells)	Miscellaneous
Chlamydomonas	1	None	None	Isogametes (alike)	Cell wall of cellulose; single nucleus; 2 flagella of equal length; chloroplast; pyrenoid to make starch
Gonium sociale	4	Platelike; gelatinous	None	Isogametes	As above; cytoplasmic connective between cells
Gonium pectorale	16	Platelike; gelatinous	None	Isogametes	As above; cytoplasmic connective between cells
Pandorina morum	16	Hollow sphere encased in a gelatinous matrix	None	Heterogametes (unlike)	As above; cytoplasmic connective between cells
Eudorina elegans	32	Hollow sphere with 2 kinds of different cells	Some?	Heterogametes	As above; cytoplasmic connective between cells
Pleodorina illinoisensis	32	Hollow sphere with 2 kinds of different cells	Four (in anterior end of colony)	Heterogametes	As above; cytoplasmic connective between cells
Pleodorina californica	64 or 128	Hollow sphere with 2 kinds of different cells	Half of cells (in anterior part of colony)	Heterogametes	As above; cytoplasmic connective between cells
Volvox perglobator	500 to thousands	Sphere preceded by platelike colony of 16 cells; body (somatic) and reproductive cells	All but about 100 cells	Heterogametes	As above; cytoplasmic connective between cells

YELLOW-GREEN ALGAE, GOLDEN-BROWN ALGAE, AND DIATOMS (PHYLUM CHRYSOPHYTA)

These plants may be unicellular, colonial, or multicellular, depending on the species. They contain yellow or brown carotenoid pigments in addition to chlorophyll, all contained in plastids. An organized nucleus is present. Flagella may be present or absent, depending on the species. Reproduction occurs (1) asexually by cell division, by motile zoospores, by nonmotile spores, or (2) sexually by isogamy.

Study preserved materials, living specimens, and prepared slides as suggested. Make careful observations and properly labeled DRAWINGS.

Diatoms. These plants are widely distributed and different species display a great variety of shapes and patterns. Their numerous shapes and delicate beauty label them as the "jewels of the plant world." The cells of the various species may be shaped like rods, discs, triangles, boats, etc. Different species are unicellular, filamentous, or colonial. The cell walls are usually composed of 2 overlapping **valves** (halves) and are often impregnated with silica, thus making them glasslike, fragile, and transparent. The siliceous cell walls are beautifully patterned with tiny **dots** and **perforations** which are accurately arranged. A **raphe** (longitudinal slit) is present in the cell wall. The **plastids** beneath the cell wall impart various colors to different species.

Reproduction occurs by **cell division,** each newly formed cell remaining in the 2 original valves. Then each new cell secretes a new valve inside each of the old valves. Hence some cells in succeeding divisions will become smaller and smaller. Finally these smaller cells regain their original size by producing **auxospores** (rejuvenescent cells). The latter may be formed in several ways but the following is typical. Each of 2 diatom cells may form a **gamete,** and the fusion of 2 gametes produces a zygote which acts as an **auxospore.** The latter elongates to maximum cell size and 2 new valves are then formed.

If desirable, examine a suspension of **diatomaceous earth** in water, noting the construction of the cell walls.

Vaucheria. This **filamentous,** golden-brown alga may be found in fresh water, on moist soils, etc. The plant (thallus) is **tubelike** and normally **not divided by cross cell walls.** Numerous **chloroplasts** (for photosynthesizing food) and numerous **nuclei** are present in the **cytoplasm** which surrounds a **central vacuole.** Reserve food is stored as oil. The multinucleated filament is known as a **coenocyte** (Gr. *koinos,* shared; *kytos,* cell) and develops by the elongation of the cell whose nucleus divides repeatedly without forming cross cell walls.

Asexual reproduction may occur in several ways. (1) In aquatic species a **sporangium** (spore case) is produced by the formation of a cross wall near the tip of a branch. The protoplast of this cell becomes a **motile, multiciliated, multinucleated zoospore** which develops into a new filament. (2) In species on moist soil **asexual, nonmotile spores** may be formed as described above. (3) In other terrestrial species the coenocytic protoplast may divide into numerous segments, around which heavy walls are secreted to form **asexual resting spores.**

Sexual reproduction is accomplished by **oogamy** in which sex cells of **unequal size (heterogametes)** unite, the **egg being nonmotile.** Both sexes are present on the same filament. The **antheridium** is a hooklike branch in which numerous biflagellated **sperms** with a single **nucleus** are produced. The **oogonium** is an enlarged structure containing an **egg** supplied with **food** and a single **nucleus.** The fertilized egg (zygote) develops into a resistant **oospore** which later germinates to form a new filament.

Study prepared slides and preserved and living specimens as supplied.

DRAW and label all structures correctly.

BROWN ALGAE (PHYLUM PHAEOPHYTA)

The plant body of these multicellular, marine algae may show considerable differentiation, as in certain kelps, with their rootlike **holdfasts** for attachment, a stemlike **stipe,** and leaflike **blades.** Gas-filled **bladders** may be present for buoyancy purposes. The brownish pigment fucoxanthin masks the chlorophyll. Usually there are several plastids per cell. An organized nucleus is present.

Depending on the species reproduction may occur (1) asexually by fragmentation, by motile spores, by nonmotile spores or (2) sexually by isogamy, heterogamy, or oogamy. When present, pear-shaped reproductive cells bear 2 lateral flagella of unequal length. Brown algae possess alternation of generations.

Study preserved materials, living specimens, and prepared slides as suggested. Make careful observations and properly labeled DRAWINGS as suggested.

Kelp (Laminaria). This multicellular marine, brown alga is attached by rootlike **holdfasts.** The surface of the leaflike **blades** bears patches of **zoosporangia. Motile zoospores** formed in the zoosporangia produce 2 types of microscopic **gametophytes.** The small **male gametophyte** is a simple, branched filament which bears terminal **antheridia.** Each antheridium produces one biflagellated **sperm,** the **flagella being of unequal length.** The small **female gametophyte** is a short filament also which bears **oogonia,** each with one egg. Fertilization by oogamy produces a **zygote** which eventually produces a mature **sporophyte** stage. Hence there is an **alternation of generations** between the more conspicuous, multicellular sporophyte and the microscopic gametophyte.

Rockweed (Fucus). This multicellular, marine, brown alga consists of a leathery, dichotomously branched **thallus.** Some branches bear gas-filled **bladders** for buoyancy purposes. Enlarged tips of branches are called **receptacles** which contain small openings leading into internal cavities called **conceptacles.** The **sex organs** are within the conceptacles. In some species the **male antheridia** are on one plant and the **female oogonia** on another, while in other species the male and female organs are on the same plant, even being within the same conceptacle.

When mature, each female **oogonium** contains several eggs. Among the oogonia are multicellular, branched, hairlike paraphyses. The enlarged male **antheridia,** borne on the paraphyses, produce numerous, pear-shaped **sperms,** each with **2 unequal, lateral flagella.** In sea water a sperm and an egg unite to form a **zygote** which eventually produces a new *Fucus* plant by repeated cell divisions. The egg is larger than the sperm. *Fucus* also reproduces asexually by **fragmentation.** In *Fucus* the gametophyte generation is reduced to merely the gametes which possess the single (haploid) number of chromosomes, while the cells of the conspicuous, sporophyte generation contain the double (diploid) number.

RED ALGAE (PHYLUM RHODOPHYTA)

These algae may be relatively simple or branched, in the form of a ribbon or a sheet. Most species are attached (sessile), marine algae but a few live in fresh waters. Each cell has a nucleus, central vacuoles, and one or more plastids. Some species possess pyrenoids. Chlorophyll is associated with a red pigment, phycoerythrin, and sometimes with a bluish phycocyanin. Broad cytoplasmic strands connect adjacent cells.

Most red algae reproduce sexually by oogamy. None of the sex cells or asexual reproductive cells bear flagella. Many red algae possess an alternation of generations between a free-living sporophyte and a free-living gametophyte.

Study preserved materials, living specimens, and prepared slides of such types as suggested. Make careful observations and properly labeled DRAWINGS.

Nemalion. This cylindrical, forked red alga is attached to rocks along the seacoast. The **thallus** (body) consists of a mass of interwoven, branched, **threadlike structures** surrounded by a **gelatinous material.** Some branches bear brushlike **filaments** whose tips are divided into short, male **antheridia,** each containing one **nonmotile sperm.** Tips of other branches bear female structures, each with an enlarged, basal **carpogonium.** The latter bears an **egg** and an elongated, hairlike, tubular **trichogyne** to receive the sperm from the water. The sperm nucleus descends within the trichogyne to the carpogonium where it fuses with the egg to form a **zygote.** From the carpogonium are formed clusters of short **filaments** whose tips produce **asexual, nonmotile carpospores.** The latter germinate to form a new *Nemalion* plant.

Polysiphonia. This multibranched red alga grows on rocks of the seacoast. The **main axis** and **larger branches** consist of a **central core** made of a single row of elongated **core cells** and surrounded by a layer of **jacket cells.** The core cells are connected with each other by **strands of cytoplasmic connectives** which form tubelike **siphons,** hence the name *Polysiphonia.* Numerous disclike **red plastids** containing **phycoerythrin** mask the **chlorophyll.**

This alga is **dioecious,** male gametes being produced by one plant and female gametes by another. The lateral branches of male plants bear clusters of **antheridia** which produce many **nonmotile sperms.** The female **carpogonia** are borne on the side branches of other plants. Each carpogonium has an elongated **trichogyne** to receive and conduct the sperm to the carpogonium where the sperm fuses with the egg nucleus to form a **zygote.**

After numerous cell divisions there are produced many **filaments** whose tips form many **carpospores.** Other filaments of the plant form an **urn-shaped enclosure (cystocarp)** around the carpospores. When the latter escape through an opening they develop into new plants which produce **tetrasporangia,** each with **4 nonmotile tetraspores.** The sporangia are borne on the central core and lie just beneath the jacket cells. When liberated each tetraspore forms a *Polysiphonia* plant either with **antheridia** or with **carpogonia.** The number of chromosomes is reduced one-half (reduction division) when tetraspores are formed.

Thus the life cycle consists of (1) separate male and female plants, (2) zygote and asexual carpospores, (3) plants with sporangia which produce tetraspores, (4) male and female plants.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were the studies of algae sufficiently extensive to supply valid data? If desirable, make a TABLE of the characteristics of the 5 phyla of algae, comparing and contrasting the representatives of these groups on the following: (1) method of food manufacture, (2) plastids, (3) pigments, (4) organized nucleus, (5) cytoplasmic strands between adjacent cells, (6) presence or absence of motile cells (vegetative and reproductive).

When we study a series of algae from the blue-green types through the red types is there a progressive increase in complexity and development toward a higher type of plant? Give specific proof for your answer. How may additional, pertinent information be secured?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw logically from an accurate interpretation of the collected information? Do the conclusions prove or disprove the hypotheses and problems? Why do you say so? What additional conclusions not directly associated with the problems can you draw? Be sure your conclusions are all valid.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable information. Recheck particularly those places where you may have made errors in observation or interpretation. Repeat any observations which you think may have been erroneous.

Simple plants without chlorophyll—fungi

Bacteria—fission fungi (phylum Schizomycophyta)

1. Problems

How are such simple, unicellular bacteria constructed so as to be able to perform all of the activities necessary for life? How can they secure food without the presence of chlorophyll? Do various types of bacteria possess structures and functions whereby they may be distinguished and classified? By what process do bacteria reproduce in approximately 30 minutes? How do some species locomote from place to place and how do some species resist certain abnormal conditions for rather long periods of time? Do certain types cause diseases in plants, animals, and human beings while others are actually beneficial?

2. Preliminary observations and pertinent data and information

LIST all of the reliable and accurate information which you have about bacteria. Record only that information which you know to be true.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable information which you have, formulate hypotheses from which you may work toward the solution of the problems. Suggest specific methods of investigation whereby you may secure additional, pertinent information with which to prove or disprove the hypotheses and problems. Be specific in your suggestions of methods of investigation and experimentation.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

In order to secure information make such of the following studies as suggested by the instructor.

Colonies of bacteria. Secure 4 Petri dishes containing a solid culture medium called agar, all of which have been sterilized in an autoclave for 20 minutes at 15 pounds pressure. Remove the cover from one dish and expose the agar to the air for 10 minutes. With a glass-marking pencil place your initials and No. 1 on the cover. With a flamed forceps place a coin on the agar of dish No. 2. Touch your finger (lightly) to the agar of dish No. 3. Use the uninoculated dish No. 4 as a control. Why? Incubate all dishes until next laboratory period and observe the numbers, sizes, shapes, and consistencies of different colonies.

Isolation of a pure culture. Each colony has arisen supposedly from a single bacterial cell which has reproduced to form a colony consisting of one type of organism ("pure culture"). Under what conditions might this not be true? Stains and various physiologic and morphologic studies may be made to test the purity of the culture. If the colony is pure part of it may be transferred to an agar slant in a test tube to be used for future studies.

The transfer to an agar slant may be made as follows: (1) flame an inoculating needle to red heat; (2) flame the cotton plug of the test tube and extinguish quickly by covering completely with the hand; (3) remove the plug and hold between your fingers; (4) flame the mouth of the tube; (5) raise the lid of the Petri dish slightly and touch the colony lightly (do not attempt to transfer some of the agar also) with the sterile needle; (6) insert the needle with the inoculum to the bottom of the slant (do not touch the tube or agar); (7) drag the needle over the agar surface lightly as you withdraw the needle; (8) flame the needle again to red heat; (9) flame the mouth of the tube and reinsert the plug; (10) label the tube and incubate. Such a culture is called an agar slant culture.

Stained bacteria. Study prepared slides of bacteria (or projected lantern slides or charts) or demonstration slides, using an oil-immersion objective, of the following: (1) spherical-shaped bacteria *(cocci)*, (2) rod-shaped bacteria *(bacilli)*, (3) spiral-shaped bacteria *(spirilla)*, (4) rod-shaped bacteria which contain internal spores, (5) rod-shaped bacteria which possess flagella, (6) bacteria in the process of dividing by fission.

DRAW each of the above properly labeled.

Locomotion of living bacteria. Study a demonstration slide (with oil-immersion objective if possible) of living bacteria which display active locomotion. This so-called "hanging-drop" slide is prepared as follows. Clean a large cover glass and place on it a drop of liquid containing living, motile bacteria such as the intestinal organism, *Escherichia coli.* Place a ring of petroleum jelly around the depression of a concave slide. Invert this slide over the drop of culture and quickly turn the slide over so that the drop of culture is suspended in the middle of the cover glass with the latter sealed securely in position on the slide. By reducing the amount of light and focusing carefully on the edge of the drop of culture attempt to observe the bacterial rods locomoting from place to place. Because the bacteria are not stained great care must be exercised in order to see them. Use the fine adjustment to bring them into focus and to keep them visible. Contrast this locomotion with Brownian movement. Do you observe any flagella? Why?

Physiologic activities of bacteria. Two of these are the fermentation of sugar and the production of enzymes.

FERMENTATION OF SUGAR. Fill a Dunham type of fermentation tube (small test tube inverted within a larger test tube) with a 1% lactose (sugar) broth medium, plug with a cotton plug, and autoclave properly. Inoculate the lactose broth near the bottom of the larger tube with a culture of *Escherichia coli.* Incubate at 37° C. until the next laboratory period. Also incubate an uninoculated fermentation tube of lactose broth as a control. Why? Observe gas formation (collected in the smaller, inverted tube). What is the source of the gas? What is this gas? Test the broth for acid or alkali production with litmus paper (or similar indicator paper). What is the explanation for these phenomena?

PRODUCTION OF ENZYMES. Inoculate a tube of sterile gelatin medium by stabbing the center with a straight inoculating needle containing some bacteria such as *Proteus vulgaris.* Incubate until the next laboratory period. As a control incubate an uninoculated tube of gelatin. Why? Observe any liquefaction, noting whether the liquid is due to the incubating temperature or to the presence of protein-liquefying enzymes. If due to the incubating temperature the gelatin should resolidify when cooled with cold water or ice. What is the source of the enzymes? What functions do such enzymes perform? Would you expect to find *Proteus vulgaris* common where protein materials are being liquefied?

Disease-producing (pathogenic) bacteria. A majority of bacteria are not harmful but some produce diseases in plants, animals, and human beings. In order to secure some information in this connection, read your text or other references concerning the following. (1) List 6 plant diseases with the bacterial causal agent of each; (2) list 6 animal diseases with the bacterial causal agent of each; (3) list 12 human diseases with the bacterial causal agent of each.

Beneficial bacteria. Even though a majority of bacteria are not harmful and many kinds produce diseases in various kinds of living organisms, there are some which are actually beneficial. In order to secure some information in this connection read in the text, or other references, about the roles of bacteria in such phenomena as (1) the retting of flax, (2) the fermentation of silage, (3) the curing of tobacco, (4) the production of sauerkraut, (5) the fixation of nitrogen in the soil by nitrogen-fixing bacteria. This list is by no means complete but it gives an idea that certain bacteria are useful.

5. Evaluation of collected data and information

Were your studies sufficiently extensive to give accurate information? Why do you say so? Explain any instances where you may have made errors in observations or interpretations, including reasons why you may have made them. Do you think that your information is sufficient to enable you to secure additional data on bacteria. How might additional information be secured?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from an accurate interpretation of the collected information? Do these conclusions prove or disprove your hypotheses and problems? Why do you say so? LIST all the conclusions concerning bacteria which are justified by the information which you secured. What were your sources of information in addition to the studies performed in the laboratory? Were these sources reliable? Why?

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable information. Might some of the information have been inaccurate because so few observations were made? Would repetitions of all observations and experiments several times be more reliable? Why? In general is it more desirable to base conclusions on numerous observations rather than on a single one? Why do you say so?

Simple plants without chlorophyll—fungi (cont'd)

Slime fungi (phylum Myxomycophyta) and true fungi (phylum Eumycophyta)

1. Problems

How are slime fungi constructed whereby they have, in part, certain traits commonly attributed to plants and some other traits attributed to lower animals? How do certain plants possess the ability to locomote from place to place? Do some stages of slime fungi ingest solid particles of food in an animal-like manner? What traits do the so-called higher, true fungi possess which lower fungi do not? Do some fungi undergo a complex life cycle and reproduce by a variety of spores? Do certain pathogenic (disease-producing) fungi alternate between two hosts in their life cycle? How can fungi perform the various activities necessary for living without the benefit of true leaves, stems, or roots? How do fungi, which are without chlorophyll, secure their foods? Do fungi produce diseases in plants, animals, and human beings? How do many fungi live saprophytically in nature? In what ways are certain fungi beneficial to man?

2. Preliminary observations and pertinent data and information

RECORD all of the reliable and accurate information which you have concerning slime fungi and true fungi. Record only that information which you know to be accurate.

3. Formulation of hypotheses and determination of methods of investigation

From your reliable information formulate hypotheses from which you may work in the solution of the problems. Suggest specific methods of investigation whereby you may secure additional, reliable information which relates to the problems.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

SLIME FUNGI (PHYLUM MYXOMYCOPHYTA)

These slimy, saprophytic fungi are found in moist places. The ameba-like body called a plasmodium contains numerous nuclei and locomotes by means of pseudopodia. Solid food particles are ingested in a way similar to that of certain lower animals. The plasmodium produces numerous sporangia (spore cases) which vary with the species as to size, form, and color. Internally the sporangium contains a network of fibers (capillitium) in the meshwork of which are formed many unicellular, nonmotile spores. Each germinated spore forms 1 to 4 swarm spores (myxamebae), each with 2 flagella. After several divisions 2 myxamebae fuse to form a zygote. Several zygotes may join to form a new plasmodium in which the nuclei are not fused.

Study preserved specimens, museum mounts, living specimens, prepared slides, and projected slides of such representative types as suggested by the instructor. Make careful observations of all of the characteristics you can.

Stemonitis. The **plasmodium** is a naked, multinucleated mass of protoplasm. If living plasmodia are available observe the **streaming of the protoplasm** and the formation of temporary, fingerlike **pseudopodia.** The plasmodium often assumes the form of a fan-shaped network of **veinlike branches** and may be brightly colored. The plasmodium flows over the substratum in an ameboid manner engulfing food particles which are ingested in animal-like **food vacuoles.** Living plasmodia may be maintained in shallow glass dishes by feeding them bacteria or yeast cells.

DRAW a plasmodium of *Stemonitis* correctly labeled.

Although the vegetative plasmodium is animal-like, reproduction occurs by plant-like processes. Thin-walled **sporangia** (spore cases) arise from the plasmodium at the tips of slender **stalks.** Observe the **capillitium** within the sporangium and the unicellular, nonmotile, air-borne **spores.** Upon germination the spores undergo a series of stages which culminate in a method of **sexual reproduction** and the formation of a zygote. The latter eventually forms a new plasmodium.

DRAW a sporangium with spores, properly labeled.

Lycogala. This slime fungus is common on moist, rotten logs. In addition to the descriptions already given observe particularly the **sporangia** which may be about ¼ inch in diameter and without long stalks. When young, the sporangia are white but later turn pink, becoming brown when mature.

DRAW a sporangium of *Lycogala* correctly labeled.

Physarum. Make studies of this type of slime fungus and DRAW.

TRUE FUNGI (PHYLUM EUMYCOPHYTA)

True, higher fungi vary in size, form, physiology, and methods of reproduction, depending on the species. All true fungi possess heterotrophic nutrition (unable to make their own foods), being either saprophytes or parasites. Most species are composed of filamentous **hyphae,** a mass of which is called a **mycelium.** In some species the hypha is unicellular, in others it is multicellular. In some species certain hyphae contain yellow, orange, red, or other pigments. All true fungi reproduce by means of some types of spores, but other methods of reproduction may also occur in various species.

Study preserved materials, museum mounts, living specimens, prepared slides, and projected slides of such representative types as suggested. Make careful observations of all characteristics.

Algalike fungi (class Phycomycetes)

Black bread mold (Rhizopus nigricans). The grayish **hyphae** of this saprophytic fungus are common on such moist organic materials as bread, fruits, animals, etc. Younger hyphae may be branched and **nonseptate** (without cross walls) and contain numerous **nuclei.** Older hyphae may be **septate** (cross walls). Rootlike hyphae, called **rhizoids,** anchor the plant and absorb materials from the substratum. Other hyphae, called **stolons,** grow on the surface and give rise to spore-forming **sporangiophores.** The tips of the latter bear enlarged **sporangia** (spore cases) in which are formed asexual, nonmotile, air-borne **sporangiospores.** The latter germinate to form new hyphae.

DRAW some hyphae with sporangiophores, correctly labeled.

Sexual reproduction occurs by forming small branches, called **progametes,** between adjacent hyphae, which fuse at their tips. *Rhizopus nigricans* is **heterothallic** (two different types of hyphae, called + and –). Each progamete forms a single, multinucleated **gamete.** Two gametes fuse in a fertilization process called **conjugation** to form a thick-walled **zygospore.** The latter germinates to form a new hypha.

DRAW to show conjugation of *Rhizopus.*

Water mold (Saprolegnia). This aquatic, saprophytic fungus possesses heterotrophic nutrition, securing food from dead plants and animals. Slender **hyphae** bear tapering ends for penetration, and branched hyphae contain enlarged tips called **zoosporangia.** The latter produce **biciliated zoospores** (**swarm spores**), each with **2 terminal cilia.** After swimming in the water they eventually lose these cilia and become surrounded with a **wall.** Later each escapes from the wall and now possesses **2 lateral cilia.** From the latter type of zoospore a new hypha develops.

DRAW hyphae with zoosporangia and zoospores, correctly labeled.

Sexual reproduction is **heterogamous** whereby are developed enlarged, unicellular **oogonia** and clublike male **antheridia.** Each oogonium contains several **eggs.** The antheridia develop **antheridial tubes** which penetrate the oogonia and transport the **male nuclei** to the oogonia where fertilization of the egg results in a thick-walled **oospore.** The latter develops into a new hypha. *Saprolegnia* has a homothallic method of reproduction (both antheridia and oogonia on the same plant).

DRAW to show the sexual reproduction of *Saprolegnia.*

Ascus (sac) fungi (class Ascomycetes)

Penicillium. This bluish-green mold is **filamentous** and **septate** (cross walls). Certain spore-bearing hyphae, called **conidiophores,** bear chains of small, colored **conidiospores** (**conidia**) at their tips. Masses of conidiophores resemble tiny brushes, hence the name *Penicillium.* Saclike structures, called **asci,** contain **ascospores** on certain hyphae. An ascospore germinates to form a new hypha.

DRAW a conidiophore with conidiospores and an ascus with ascospores.

Cup fungus (Peziza). This saprophytic fungus is common in damp places. The cup-shaped body (**ascocarp**) is composed of closely packed **hyphae** and is really an **apothecium** with its inner surface composed of a layer called the **hymenium.** The latter is composed of cylindroid, sac-shaped **asci** and numerous, sterile hyphae called **paraphyses.** Each ascus usually contains 8 **ascospores,** each of which will develop into a new cup fungus.

DRAW an apothecium with its ascospores and paraphyses. Label correctly.

Bread yeast (Saccharomyces). This unicellular fungus is usually without hyphae and each ovoid cell has a large **nucleus.** Asexual reproduction occurs by budding in which **buds** (small protuberances) are projected from the cell. The bud may free itself or remain attached and form more buds.

DRAW a yeast cell showing buds and other parts correctly labeled.

Under certain conditions a yeast cell may become a single **ascus** in which **ascospores** (usually 4) are produced. In some cases 2 yeast cells may fuse before ascospores are formed. A yeast cell contains a double number (2N) of chromosomes, while ascospores contain a single number (N). Two spores unite to form a vegetative yeast cell again.

DRAW a yeast ascus with ascospores correctly labeled.

Basidium (club) fungi (class Basidiomycetes)

Mushrooms. These saprophytic fungi secure food from dead organic materials in soils, woods, etc. The vegetative body consists of masses of **septate hyphae,** some of which penetrate the substratum. The **sporophore** ("mushroom") consists of a stalklike **stipe** and an umbrella-shaped **pileus,** on the under surface of which are sheetlike **gills.** The latter are composed of plates of **compacted hyphae** which bear club-shaped **basidia.** The latter bear **basidiospores** (usually 4) on small stalks called **sterigmata.** Each basidiospore germinates to form a new hypha.

DRAW a sporophore of a mushroom correctly labeled.

Bracket (shelf) fungi. These fungi are called pore fungi because the **brackets** contain hundreds of tiny **tubes** which open through **pores** on the under surface. The **bracket** (**sporophore**) is often tough, woody, and may be composed of several layers. The internal hyphae around the tubes form club-shaped **basidia** which bear

basidiospores. The latter escape through the pores and germinate to form new hyphae.

DRAW a sporophore of a bracket fungus, correctly labeled.

Black stem rust of wheat. The parasitic fungus which causes black rust on the stems of wheat is called *Puccinia graminis.* The complex life cycle of this pathogenic fungus may be stated briefly as follows.

(1) During the summer the hyphae live in the stems and leaves of wheat plants where they form surface blisters called **uredinia** in which reddish orange **unicellular uredospores (summer spores)** are produced.

(2) In late summer the hyphae form bladderlike pustules called **telia** which produce many two-celled, thick-walled, resistant **teliospores (winter spores).** The latter constitute the "black rust" stage and remain dormant during the winter.

(3) During germination (following spring) each teliospore forms a club-shaped **basidium** with **4 basidiospores.** The latter are wind-borne to the leaves of the common barberry where they germinate and send hyphae into the leaf tissues. (Note: This common barberry is not to be confused with the cultivated Japanese barberries.)

(4) The hyphae form small, flask-shaped **pycnia (spermagonia)** on the upper surface of the barberry leaves. In the pycnia are formed numerous, small **pycniospores (spermatia)** at the tips of the hyphae. The pycniospores escape to the upper surface of the barberry leaves and are of two types (plus and minus strains). Likewise the basidiospores and the hyphae into which they develop are plus and minus strains.

(5) When a plus pycniospore fuses with a minus pycniospore a mycelium develops which produces yellowish red **aeciospores (spring spores)** in small cuplike **aecia** on the lower surface of barberry leaves.

(6) In the spring the **aeciospores** are carried to wheat plants where they germinate to form hyphae which again form **uredinia.** The latter produce **uredospores,** thus completing the life cycle between two host plants.

DRAW the life cycle of Black Stem Rust, showing all stages on the proper hosts and all parts correctly labeled.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive to give enough reliable information? Explain instances where errors may have been made in observations and interpretations. How might such errors be corrected?

6. Drawing logical conclusions based on the data and facts obtained

LIST the conclusions which you can draw from a logical interpretation of the collected information. Do these conclusions prove or disprove the hypotheses and problems? Explain how you might secure additional, pertinent information and data relating to the problems concerning slime fungi and the members of the 3 classes of true fungi. Are all of your conclusions justified by the evidence available?

7. Rechecking all steps

Recheck all procedures which you followed in attempting to secure reliable information. Were all observations made carefully? Might some of the data which you secured be inaccurate because you made so few observations? Did you repeat all observations a sufficient number of times to ensure accuracy? In general, is it more desirable to base conclusions on numerous observations rather than on a single one? Why do you say so?

Intermediate plants with chloroplasts—bryophytes

Liverworts and true mosses (phylum Bryophyta)

1. Problems

In what ways are liverworts and true mosses structurally and functionally above the algae and fungi? Why are leaflike structures, stemlike axes, and hairlike rhizoids which may be present not considered to be true leaves, stems, and roots? Even though bryophytes are terrestrial plants, do they require considerable amounts of moisture? In contrast to algae and fungi do bryophytes possess multicellular sex organs with a sterile, jacket layer surrounding them? Do bryophytes produce multicellular embryos (within the multicellular female sex organs) in contrast to algae and fungi? Do bryophytes possess an alternation of generations in which a rather conspicuous gamete-producing gametophyte generation alternates with a parasitic, spore-producing sporophyte generation? Are bryophytes of economic importance?

2. Preliminary observations and pertinent data and information

RECORD any reliable information you may have concerning liverworts and true mosses. Be accurate in your recording.

3. Formulation of hypotheses and determination of methods of investigation

From your reliable, preliminary information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods whereby you may secure additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

The bryophytes consist of liverworts and true mosses which superficially may not seem to be related but careful investigations will reveal the many traits which they have in common.

Study preserved materials, museum mounts, living specimens, prepared slides, and projected slides of such representatives as suggested.

Liverworts (class Hepaticae)

Marchantia (thalloid liverwort). The flat, lobed, thallose bodies grow prostrate on the substratum, and the upper and lower surfaces are different. The upper contains **rhomboidal areas,** each with a **pore** for exchange of gases. Internally there are **air chambers** with **columns of cells** containing **chloroplasts** for **photosynthesis.** Rootlike **rhizoids** anchor the thallus and absorb materials. Special bodies called **gemmae** are formed in **gemmae cups** for asexual reproduction.

DRAW a thallus with gemmae cups, correctly labeled.

Marchantia is dioecious, one thallus (**male gametophyte**) may bear stalklike **antheridiophores** with lobed **discs** at the tips. Male **antheridia** are borne in cavities which open on the upper surface of the discs. Each antheridium is an enlarged structure which produces coiled, **biflagellated sperms** (**gametes**).

DRAW an antheridiophore and sperms, correctly labeled.

Another thallus (**female gametophyte**) may bear stalklike **archegoniophores** with terminal **discs with fingerlike rays.** Female **archegonia** are borne on the under surface of these discs. Each archegonium has a hollow, tubular **neck** and an enlarged **venter** with a single **egg** at its base. Waterborne sperms swim to the venter where fertilization produces a **zygote.**

DRAW an archegoniophore and an egg, correctly labeled.

By repeated cell divisions the zygote forms a **multicellular embryo** from which a spore-producing **sporophyte** develops. The latter consists of a **foot** which is embedded in the disc of the female gametophyte and an enlarged **capsule** (**sporangium**). The latter produces numerous **spores,** each of which has elongated, spiral-shaped **elaters.** Moisture affects the elaters to assist in the expulsion of spores from the capsule. Study spores under both moist and dry conditions, noting carefully the different status of the elaters. Spores germinate to form new male and female gametophytes.

DRAW a sporophyte and spores with elaters (under both moist and dry conditions).

Porella (leafy liverwort). These plants form a green mass of prostrate growth on moist rocks. *Porella* has **3 rows of leaflike structures** attached to **stemlike axes** which are attached by fibrous **rhizoids on their lower surface.** The leaflike structures of the gametophyte consist of **one layer of cells** and **without a midvein** (in contrast to true mosses).

The male **antheridia** are borne in the axils of the leaflike structures, while the female **archegonia** are borne at the apex of the main shoot or its branches. The fertilized **egg** develops eventually into a **sporophyte** which is parasitic on the archegonium. When mature the sporophyte consists of a **foot, stalk,** and a **capsule** (**sporangium**). The latter opens at the tip by means of **valves** and produces **spores** with **elaters** as in thalloid liverworts.

DRAW to show the above structures accurately labeled.

True mosses (class Musci)

Polytrichum (hairy-cap moss). These mosses grow in moist places and each individual plant consists of a **stemlike axis** with attached **leaflike structures.** Rootlike **rhizoids** anchor the plant and absorb materials.

Polytrichum is dioecious (2 sexes on different plants). In male plants several **antheridia** are borne in a cluster at the tip of the axis and are separated by multicellular, sterile, hairlike **paraphyses.** Each antheridium consists of a short **stalk** and an enlargement which produces coiled, male **sperms,** each bearing **2 long terminal flagella** (**biflagellated**).

DRAW a male moss plant with antheridia and sperms, properly labeled.

In female plants several **archegonia** are borne in a cluster at the tip of the axis and separated by **paraphyses.** Each archegonium consists of a **stalk** and an enlarged **venter** which contains an **egg.** When mature a **canal** leads through the venter to permit the sperm to swim to the egg where fertilization results in a **zygote.** By repeated cell divisions the latter forms a **multicellular embryo** which is parasitic on the female gametophyte.

DRAW a female moss plant with archegonia and eggs, properly labeled.

From the embryo develops a **sporophyte** consisting of an elongated **stalk** at the tip of which is a spore-producing **capsule** (**sporangium**). The latter is covered with a hairy cap, the **calyptra.** Beneath the calyptra is a lidlike **operculum.** Beneath the latter is a ring of hygroscopic teeth, called the **peristome,** to assist in spore dissemination.

DRAW a moss sporophyte, properly labeled.

Each spore germinates to form a **thread-like protonema** which bears **chloroplasts. Buds** on an older protonema produce a new male or female plant. Hence there is an alternation of generations between gametophyte and sporophyte generations.

DRAW a moss protonema, correctly labeled.

Sphagnum (peat moss). These mosses are common in bogs and other moist places. The upright, branched **axes** may be a foot long and bear **leaflike structures.** The latter contain two kinds of cells, one containing **chloroplasts** for photosynthesis, and another for water storage. The **water storage cells** have **2 outside openings** and are empty so that much water may be stored.

DRAW to show the above structures, properly labeled.

Depending on the species, male **antheridia** and female **archegonia** may be present on different branches of the same plant (monoecious) or on different plants (dioecious). A fertilized **egg** forms a **zygote** which develops into a **multicellular embryo** from which is formed a **sporophyte** plant (parasitic on the archegonium). The sporophyte consists of an enlarged, spore-producing **capsule,** a short, stalklike **seta,** and a basal **foot.** Because of a short seta the gametophyte develops a so-called **pseudopodium** at the base of the foot in order to elevate the capsule.

DRAW to show the above structures, correctly labeled.

A germinated spore forms a thin, lobed, platelike **prothallus (prothallium)** from which an adult gametophyte develops. Hence the life cycle alternates between the gametophyte and parasitic sporophyte generations.

DRAW a prothallus stage.

5. Evaluation of collected data and information

Do the collected data and information tend to prove or disprove the hypotheses and problems? Were your studies sufficiently accurate and extensive to give additional, reliable information? Why do you say so? Explain specific instances where errors in observation or interpretation may have been made, including methods for correcting them.

6. Drawing logical conclusions based on data and facts obtained

List all of the conclusions which you can draw from a logical interpretation of the collected information. Do these conclusions prove or disprove the hypotheses and problems?

7. Rechecking all steps

Recheck all procedures which you followed in securing reliable information, including particularly those areas where errors may have been made. Suggest methods whereby additional, pertinent information might be secured concerning liverworts and true mosses. Explain how such additional information might assist in the solution of the problems.

Higher plants with true leaves, stems, and roots

Club "mosses," horsetails, and ferns (phylum Tracheophyta)

1. Problems

Do higher plants such as club "mosses," horsetails, and ferns possess structures and functions which place them above the bryophytes? What structures must be present in order to form true leaves, stems, and roots? Is it usual for stems to be located horizontally and underground as in the case of rhizomes? Do certain types of club "mosses" and horsetails possess sporangia-bearing sporophylls which may be arranged in the form of strobili (cones)? Do spores of such plants as horsetails possess moisture-sensitive elaters for spore dispersal? Is the sporophyte generation of these 3 groups of plants relatively larger than comparable sporophytes of the bryophytes? Is the gametophyte generation of these 3 groups of plants relatively smaller than comparable gametophytes of the bryophytes? Do plants of these 3 groups undergo alternation of generations as do the bryophytes?

2. Preliminary observations and pertinent data and information

RECORD accurately any information which you may have concerning club "mosses," horsetails ("scouring rushes"), and ferns. Be sure that your information is correct and pertinent.

3. Formulation of hypotheses and determination of methods of investigation

From your reliable, preliminary information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods whereby you may secure additional pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

The club "mosses," horsetails, and ferns all possess vascular tissues for circulation purposes, so are placed in the same phylum but in different subphyla as shown below.

Study preserved materials, museum mounts, living specimens, prepared slides, and projected slides of such representatives as suggested. Make all observations carefully.

CLUB "MOSSES" (SUBPHYLUM LYCOPSIDA)

Lycopodium. The plants of this genus have prostrate, branching **rhizomes** (underground stems) which may be on the surface or below ground. Arising from the rhizome are numerous **upright stems with**

small, mosslike (scalelike) **true leaves** and clusters of **sporophylls** (sporangia-bearing leaves) which may form club-shaped **strobili (cones)** at the tips. In some species single sporangia are borne on the upper surface of the sporophylls. The spirally arranged leaves have **stomata** (pores) for exchange of gases. **True roots** are present. Rather simple **vascular tissues** are present for circulation purposes. Club "mosses" are so named because of the mosslike leaves and the spore-bearing organs which are often club-shaped. Are they really true mosses? Why not? Because of their prostrate growth and somewhat permanent green leaves they are often called "ground pines."

DRAW a *Lycopodium* sporophyte (with leaves, stems, roots, sporophylls, and their sporangia) correctly labeled.

The spores are alike (homosporous). A germinated spore develops into a relatively small, inconspicuous, colorless **young gametophyte (prothallus)** in the ground (subterranean) but parts may be above ground and green. The prothallus (prothallium) later contains male, sperm-producing **antheridia** and egg-producing **archegonia** on the upper surface of the gametophyte which is anchored by rootlike **rhizoids. Biflagellated** sperms swim to the **egg.**

DRAW a *Lycopodium* gametophyte with antheridia and archegonia, labeling all parts accurately.

A **zygote** (fertilized egg) develops into a **multicellular embryo** which later forms a **young, leafy sporophyte.** The latter at first is parasitic on the gametophyte but later is independent. A so-called **foot** is present for absorption purposes.

***Selaginella* (small club "mosses").** The plants of this genus have creeping, **branched stems** with **true roots** and tiny, triangular, green **leaves** (4 rows, 2 larger and 2 smaller). **Stomata** permit the exchange of gases. A membranous **ligule** at the base of each leaf is in contrast to *Lycopodium.* Rather **simple vascular tissues** are present for circulation purposes.

Conelike **strobili** are present at the tips of branches. In a strobilus the upper surface of each male **microsporophyll** has in its axil (upper angle) a small **microsporangium** which produces small **microspores.** Female **megasporophylls** produce 4 large, thick-walled **megaspores** in each **megasporangium,** located in the axil.

DRAW a sporophyte with leaves, stems, roots, and strobili, all correctly labeled.

DRAW sporophylls (enlarged) to show microsporangia and megasporangia.

Selaginella produces two kinds of spores (heterosporous). A **microspore** develops into a small, parasitic **microgametophyte** within the **microsporangium.** A **megaspore** develops into a female **megagametophyte** within the **megasporangium.**

Each small microgametophyte consists of a sperm-producing **antheridium** and a **vegetative cell.** Each megagametophyte possesses several egg-producing **archegonia and rhizoids** and may possess **a little** chlorophyll. **Biflagellated sperms** swim to the **egg.**

DRAW *Selaginella* gametophytes showing antheridia and archegonia, properly labeled.

A **zygote** (fertilized egg) develops into a **multicellular embryo** which later forms a **young, leafy sporophyte.** At first the latter is parasitic on the gametophyte but later is independent. A so-called **foot** is present for absorption purposes.

HORSETAILS (SUBPHYLUM SPHENOPSIDA)

Equisetum. Plants of this genus have small, **wedge-shaped, or scalelike, true leaves** arranged in **whorls** at the **nodes (joints)** of **hollow stems.** The latter are roughened with **ribs** and impregnated with **silica** (useful for scouring purposes). A simple vascular system of **vascular bundles** (phloem and xylem tissues) is present.

A horizontal, branched **rhizome** (underground stem) usually bears two types of **aerial stems:** (1) sterile, green, branched, **vegetative stems** for photosynthesis and (2) fertile, colorless, unbranched, **reproductive stems** with a terminal **strobilus (cone).** The green stems appear bushy because of many whorled branches at the nodes, hence the name horsetails.

DRAW a rhizome with vegetative and reproductive stems, including a strobilus.

A strobilus consists of many shield-shaped **sporangiophores**, each of which contains from 5 to 10 **sporangia.** The latter produce **spores** which are alike (homosporous) and each has ribbonlike **elaters** which are affected by moisture and assist in spore movements. Study spores under moist and dry conditions, noting the status of the elaters.

DRAW a sporangiophore with sporangia, properly labeled.

DRAW a spore with elaters (in moist and dry conditions).

A germinated spore produces a small, green, flat, ribbonlike **young gametophyte** from which arise thin, **vertical lobes. Rhizoids** attach the gametophyte to the substratum. Female **archegonia** are present near the bases of the vertical lobes, although only the necks of the archegonia may be visible. The **antheridia** produce **coiled, multiflagellated sperms** which swim to the egg in the archegonium. The **zygote** (fertilized egg) forms a **multicellular embryo** which eventually forms a **young sporophyte plant,** thus completing the cycle of alternation of generations.

DRAW a gametophyte with antheridia and archegonia, correctly labeled.

FERNS (SUBPHYLUM PTEROPSIDA)

***Pteridium* (bracken fern).** This fern has a long, slender, subterranean **rhizome** consisting of an outer layer of thin-walled **epidermal cells** just exterior to a thick layer of mechanical, **outer sclerenchyma** for rigidity. Numerous thin-walled **parenchyma cells** occupy the interior for storage purposes. Two strands of mechanical, **inner sclerenchyma** are located near the center. Numerous **vascular bundles** (phloem and xylem tissues) of different sizes are located in various parts of the stem. Study a prepared slide of a cross section of a rhizome.

DRAW a rhizome (cross section), labeling all parts correctly.

Each **leaf (frond)** begins its development as a coiled "fiddle-head" attached to the rhizome, and as it uncoils in the air it matures into a much-divided **blade** on a slender, stalklike **petiole.** Two rows of **primary leaflets** are borne on the **central axis** of the **blade.** Several of the lower leaflets may be subdivided. The leaves contain **stomata** (for the exchange of gases) and are constructed internally somewhat like the leaves of higher plants.

DRAW a "fiddle-head" and a mature leaf.

All leaves of the bracken fern are **green** but only some of them serve as sporangia-bearing **sporophylls.** Along the edge of the underside of the sporophyll leaflets is developed a narrow band of tissue from whose surface grow numerous **sporangia. This** band may be partly covered by the curved margin of the leaflet.

DRAW a sporophyll with sporangia.

A **sporangium** consists of a **stalk,** a jacketlike **capsule,** and a row of thick-walled cells called the **annulus.** Numerous spores are formed within the capsule. The cells of the annulus are thickened on all sides, except the outer one, and are moisture-sensitive. As the annulus straightens the capsule breaks, snaps forward, and disperses spores which **are brown and irregular** in shape.

DRAW a sporangium (enlarged).

A germinated spore forms a **filamentous green prothallus (gametophyte)** with **rhizoids.** This prothallus grows to be a **heart-shaped prothallus** with a **notch** at its **anterior (apical) end.** Small, dome-shaped **antheridia** are usually most abundant on the undersurface of the **posterior (older) part of the prothallus,** where **rhizoids are** abundant. Numerous, spiral, **multiflagellated sperms (antherozoids)** are produced within the antheridia. **Archegonia are** present on the undersurface near the apical notch and consist of a basal, egg-containing **venter** with a **neck.**

DRAW a prothallus showing antheridia and archegonia.

A **zygote** (fertilized egg) forms a **multicellular embryo** (young sporophyte) which becomes 4-lobed for developing a **foot** for absorption, a **primary root,** a **stem,** and a **primary leaf.** Hence the life cycle of alternation of generations is completed.

***Polypodium* (polypody fern).** This common fern is somewhat similar to the bracken fern. Several **leaves** arise from the **rhizome** and on their under surfaces are dotlike **sori** consisting of numerous spore-producing **sporangia.** In many ferns each **sorus** is covered with a membranous **indusium.** Each sporangium is somewhat like those of *Pteridium*. The alternation of generations is similar to that already described.

DRAW a leaf of *Polypodium* showing the sori and other structures correctly labeled.

Make a TABLE summarizing the characteristics of (1) club "mosses," (2) horsetails, and (3) ferns, including the following for each: (a) sporophyte and sporangia, (b) spores and elaters, (c) gametophyte with antheridia, (d) gametophyte with archegonia, (e) alternation of generations, (f) true leaves, stems, and roots, (g) vascular tissues.

5. Evaluation of collected data and information

Do the collected data tend to prove or disprove the hypotheses and problems? Why do you say so? Were your studies sufficiently extensive and accurate to give information which you feel is reliable? Explain specific instances where you may have made errors in observation and interpretation thereby securing inaccurate information. Suggest specific methods whereby such errors may be corrected.

6. Drawing logical conclusions based on data and facts obtained

List all of the conclusions which you can draw from the logical interpretation of the collected information. Do these conclusions prove or disprove your hypotheses and problems? List additional conclusions which you have drawn which have not been suggested by the original problems. Suggest specific methods whereby you might secure additional, pertinent information concerning club "mosses," horsetails, and ferns. Explain how such additional information might assist in the further proving of the hypotheses and the solution of the problems.

7. Rechecking all steps

Recheck all procedures which you followed in securing accurate information, including especially any areas where you may have made errors. Repeat all observations which may have given doubtful information. If desirable make additional studies of the three groups of higher plants considered in this exercise.

Higher plants with exposed (naked) seeds—gymnospermous plants

Conifers (phylum Tracheophyta; subphylum Pteropsida; class Gymnospermae)

1. Problems

In what ways are the so-called gymnospermous plants (evergreens, sago palms, etc.) higher types of plants than ferns, horsetails, and club "mosses"? Do gymnospermous plants produce true seeds even though no flowers are present? Are these seeds exposed (naked) on the surface of the megasporophylls of the female cones? How does the pollen enter through the integument of the ovule which is located on the female megasporophyll? In what ways do pine stems show an increase in complexity over those of ferns? In what ways do pine leaves show an increase in specialization over those of ferns? Is the sporophyte generation of gymnosperms much larger and independent while the gametophyte is much smaller and dependent (parasitic)? Do gymnosperms develop a pollen tube through which pollen passes to the egg?

2. Preliminary observations and pertinent data and information

RECORD all the accurate information which you have regarding such gymnosperms as pine trees. Be certain that your information is correct and pertinent.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable, preliminary information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods whereby additional pertinent information may be secured.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

The gymnospermous plants include many of the narrow-leaved evergreens of which the common pine trees are good examples. Study preserved materials, museum mounts, living specimens, prepared slides, and projected slides, as suggested. Make all observations carefully and attempt to verify from living specimens in the field.

Gymnospermous plants are mainly evergreen and are usually rather large, woody, perennial plants. The true leaves on cone-bearing evergreens (conifers) may be needlelike or scalelike. Seeds are produced on the exposed surface of female megasporophylls (of female cones).

Pine trees (Pinus). The **sporophyte generation** (the pine tree) is large, complex, and independent, while the **gametophyte generation** is microscopic and parasitic on the sporophyte. On pine trees the **male cones** are produced in clusters and are smaller than the female cone. A male cone consists of numerous **microsporophylls** (each with 2 spore-producing **microsporangia**). Within the latter a **microspore mother cell** forms a **microspore (pollen grain)** which then develops into a male **microgametophyte.** A pollen grain has **2 wings** for its dispersal in the wind. A microgametophyte gives rise to a **sperm nucleus** which will unite with an egg to form a zygote.

DRAW a microsporophyll with its 2 microsporangia, properly labeled.

DRAW a pollen grain (microspore) with its 2 wings.

On pine trees the **female cone** is usually borne singly, is larger than the male cones, and consists of numerous **megasporophylls.** On the exposed surface of the latter are **2 ovules** (immature seeds) which later become true seeds. An **ovule** consists of (1) an external, protective **integument** which has a **micropyle** (small opening) for the entrance of pollen, and (2) a central **megasporangium (nucellus).** Within the latter a **megaspore mother cell** produces a single **megaspore** which then develops into a female **megagametophyte** with its 2 egg-producing **archegonia.** The **egg** is fertilized by a sperm nucleus to form a **zygote.** The latter develops into a **multicellular embryo** (with several cotyledons [embryonic seed leaves]). The embryo finally grows to form a pine tree (sporophyte). Pine **seeds** bear **wings** for wind dispersal.

DRAW a megasporophyll with its 2 ovules, correctly labeled.

Study a prepared slide of an **ovule** (in section) observing: (1) the external **integument** with its **micropyle;** (2) the **megasporangium (nucellus)** which may contain **pollen tubes;** (3) the centrally-located female **megagametophyte** with its 2 egg-producing **archegonia.**

DRAW an ovule (enlarged section) with its parts correctly labeled.

Study the needlelike **leaves** of a pine tree, noting that they occur in **bundles of 2** or more depending on the species. Study a prepared slide of a pine leaf (cross section) observing carefully: (1) the outer layer of thick-walled **epidermal cells;** (2) the mechanical, **sclerenchyma tissues** beneath the epidermis; (3) the sunken **stomata** which open into **air spaces** in (4) the **mesophyll tissues** which are used for photosynthesis; (5) numerous **resin canals** for longitudinal circulation purposes; (6) the **endodermis** composed of a single row of large, light cells; (7) **vascular bundles** composed of **phloem** and **xylem tissues** located near the center of the leaf and surrounded by (8) thin-walled **parenchyma cells.** The cell walls of the xylem tissues may appear thicker than those of the phloem.

DRAW a pine leaf, enlarged and in cross section. Label all parts.

Study sections of pine **stems** of different ages, observing the ages by the **annual rings.** Study a prepared slide of pine stem (cross section) observing carefully: (1) the thin layer of **cuticle** just exterior to (2) a layer of cutinized **epidermal cells;** (3) a layer of thin-walled **cork cells** just beneath the epidermis; (4) next a layer of **cork cambium** beneath which is (5) a layer of rounded **parenchyma cells** (known as the **cortex**); (6) just internal to the cortex is a layer of **phloem** (thin-walled sieve tubes and parenchyma) with (7) a layer of **xylem** (single-celled tracheids with pitted walls) internal to the phloem; (8) a layer of **cambium** between the phloem and xylem of each vascular bundle; (9) a central mass of **pith;** and (10) the narrow **vascular rays** which radiate through the stem and separate the various vascular bundles. The vascular bundles are arranged in the form of a cylinder and are separated from one another by the narrow vascular rays which radiate outward from the central pith. There is a layer of xylem for each year of stem growth, so there may be few or many depending on the age. These are called **annual rings.** Longitudinal **resin canals** are found in the cortex for transportation purposes.

DRAW a pine stem (cross section and enlarged) labeling all parts accurately. Fill in details in a quadrant of the circle rather than the entire stem.

5. Evaluation of collected data and information

Do the collected data and information tend to prove or disprove the hypotheses and problems? Give your reasons for saying so. Were your studies accurately done and sufficiently extensive to give reliable information? Are there instances where you made inaccurate observations or errors in interpretations? Give specific suggestions for correcting such errors.

6. Drawing logical conclusions based on data and facts obtained

List the conclusions which you can draw from the logical interpretation of the information which you collected. Do these conclusions prove or disprove your hypotheses and problems? List any additional conclusions which may not have been suggested by the original problems. Tell how you may secure additional pertinent information concerning pine trees and how this information might be used in connection with the problems.

7. Rechecking all steps

Recheck all procedures which you followed in securing accurate information, especially those areas in which you may have made errors. Repeat all observations which may have given doubtful information. If desirable, make additional studies of other gymnosperms in order to secure additional, pertinent information.

Higher plants with enclosed seeds—angiospermous plants

Flowering plants (phylum Tracheophyta; subphylum Pteropsida; class Angiospermae)

1. Problems

In what ways are angiospermous (flowering) plants higher types than gymnospermous plants? Do angiosperms possess flowers and seeds? Do all flowers possess petals, and are petals actually necessary for seed production? Are the seeds produced in an enclosed ovary? When pollen lands on the female stigma, resulting in pollination, must a pollen tube be developed through the tissues of the stigma, style, and ovary and finally to the micropyle of the ovule to ensure fertilization? Like the gymnosperms do angiosperms produce two kinds of spores, called heterospores (male microspores or pollen grains, and female megaspores)? As in gymnosperms is the sporophyte generation of angiosperms large and independent (when mature) whereas the gametophyte is microscopic and dependent (parasitic) on the sporophyte? Are angiosperms divided into two classes, called dicotyledonous plants (2 embryonic seed leaves) and monocotyledonous plants (one embryonic seed leaf), with each group possessing certain distinguishing characteristics? Do angiosperms require 2 sperms for a double fertilization process, whereas gymnosperms require only one sperm for a single fertilization process?

2. Preliminary observations and pertinent data and information

RECORD all accurate information which you have regarding the flowering (angiospermous) plants which may be of value in solving the problems. Be certain that the information is correct and pertinent.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable, preliminary information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods for securing additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Angiospermous plants possess flowers, and seeds enclosed in an ovary. There are many types which may be illustrated by studies of such representatives as the following. Study living specimens, preserved materials, museum mounts, prepared slides, and projected slides as suggested.

DICOTYLEDONOUS PLANTS

Garden bean (Phaseolus). The bean plant may be a bushlike or vinelike annual depending on the variety. The **stems** may be long and have a tendency to twine spirally due to unequal rates of growth on opposite sides. The **leaves** are **trifoliate** (3 arising from one point) and **net veined. Stomata** with **guard cells** regulate the exchange of gases.

The whitish **flowers** are **irregular** (with petals of different sizes and unequally spaced), **perfect** (both stamens and pistils), and **complete** (all 4 sets of flower parts: sepals, petals, stamens, and pistils). The **corolla** is papilionaceous (butterfly-like) and consists of 4 or 5 **petals,** some of which may be fused. The **calyx** consists of 4 or 5 green **sepals** more or less united. There are usually 10 **stamens** (9 of which may be united into a thin sheath around the pistil, while one is free). Each **stamen** bears a pollen-producing **anther** at its tip. The female **pistil** is composed of a pollen-receiving **stigma,** a filamentous **style,** and an elongated **ovary** (one carpel) which contains several **ovules (immature seeds).**

DRAW a bean flower with all parts correctly labeled.

When the ovary matures it becomes a bivalved, multiseeded pod, called a **legume.** Each seed is composed of (1) 2 protective **seed coats;** (2) an embryo consisting of 2 fleshy, similar halves known as **cotyledons** (embryonic seed leaves) in which foods are stored for use in germination; (3) an **epicotyl (plumule)** with true leaves; and (4) a **radicle** (primary root of seedling).

DRAW a bean pod (legume) (internal view) labeling all parts.

Buttercup (Ranunculus). The flower of a buttercup (or similar plant) is **complete** (all 4 kinds of floral organs present); **perfect** (stamens and pistils present); **regular** (all members of the same floral organs alike). The 5 yellow **petals** are similar and located above the 5 green **sepals.** Numerous **stamens** are arranged in a circle, with each having an enlarged, pollen-producing **anther** at the tip of a **filament.** The female **pistils** are located centrally and each is composed of a pollen-receiving **stigma,** a **style,** and an enlarged basal **ovary.** A **nectary** is a gland present at the base of each petal for producing a sweet liquid called **nectar.**

DRAW a buttercup flower with all parts accurately labeled.

Sunflower (Helianthus). The sunflower is an angiospermous, dicotyledonous plant belonging to the family *Compositae* because its so-called flower is a composite one (composed of numerous, small flowers closely grouped into a compact head). Individual flowers of such a head are of two kinds: (1) **disc flowers** whose **corolla** is tubular and which make up the main part of the head; and (2) **ray flowers** along the margin of the head and whose **corolla** is strap-shaped and petal-like on one side.

DRAW a *Helianthus* flower with all parts labeled correctly.

The mature **stems** of dicotyledonous plants such as sunflowers consist of (1) a central **pith** composed of thin-walled **parenchyma cells;** (2) **vascular bundles** arranged in a circle toward the periphery of the stem, with each bundle composed of (a) **xylem tissues** (single-celled, thick-walled tracheids and vessels) arranged toward the pith, (b) **phloem tissues** (sieve tubes with perforated sieve plates, and elongated, nucleated, companion cells) arranged toward the stem periphery, and (c) a layer of meristematic tissue, the **cambium,** separating the xylem and phloem of each bundle; (3) a cylinder of mechanical tissue called the **pericyle** and composed of thick-walled cells just external to the vascular bundles; the vascular bundles are separated from one another by radially arranged **rays** to conduct materials across the stem; the entire central core of the stem so far described constitutes what is called the **stele;** (4) a layer of **cortex** just exterior to the stele is composed of large, thin-walled cells; (5) a layer of **mechanical tissue** beyond the cortex is composed of thick-walled cells; (6) the external **epidermis** is composed of elongated, flat cells whose outer walls are impregnated with a waxy **cutin** to make them impermeable to water. Certain epidermal cells may have extensions called **hairs.**

Study a prepared slide of a cross section of a mature stem of a sunflower.

DRAW a stem of the sunflower, enlarged and in cross section. Fill in the details, properly labeled, of only a quadrant of the circle rather than a complete stem.

The mature region of a dicotyledonous **root** such as the sunflower (as shown in cross section) consists of (1) a central **stele,** (2) a surrounding cylinder of tissues called the **cortex,** and (3) the external **epidermis.**

The **stele** consists of (1) **xylem tissues** which are in the form of a cross and composed of thick-walled cells (tracheids and vessels) of various sizes; (2) **phloem tissues** located in the angles between the xylem strands of the cross are composed of sieve tubes with their companion cells; (3) **parenchyma tissue** composed of large, thin-walled cells located between the xylem and phloem; and (4) the **pericycle,** a cylindrical sheath composed of one or several layers of thin-walled cells which surrounds all of the above tissues.

The **cortex** consists of (1) **endodermis** which is the innermost, single layer of cortex cells, and (2) **parenchyma tissues** just exterior to the endodermis and composed of rounded cells of various sizes.

The **epidermis** is one cell in thickness and covers the entire root. Certain epidermal cells may have projections called **root hairs** to increase the absorption area.

DRAW a cross section (enlarged) of a mature root of a sunflower, labeling the various parts of the stele, cortex, and epidermis. Details may be drawn in merely a quadrant rather than the entire circle.

MONOCOTYLEDONOUS PLANTS

Indian corn (Zea mays). Indian corn is an angiospermous and monocotyledonous (one cotyledon or embryonic seed leaf) plant. Study a prepared slide of a cross section of a corn **stem** which is composed of (1) **parenchyma cells** of various sizes and shapes; (2) numerous **vascular bundles** scattered throughout the stem and each bundle consisting of (a) **phloem** (toward the stem periphery), which conducts liquids downward and is made of sieve tubes with their perforated sieve plates and the long, narrow companion cells; (b) **xylem** (toward the center of the stem), which conducts liquids upward and is made of large, thick-walled vessels surrounded by hollow, one-celled **tracheids;** and (c) the entire bundle surrounded by a sheath of thick-walled, mechanical, **sclerenchyma cells;** (there is no **meristematic** tissue [cambium] between the phloem and xylem, hence the bundle is "closed"); (3) a narrow layer of mechanical, **sclerenchyma tissue** composed of small, thick-walled, lignin-containing cells just beneath (4) the external layer of **epidermis,** whose cells are relatively small and thick-walled.

DRAW an enlarged cross section of a corn stem, labeling all parts.

DRAW an enlarged cross section of a vascular bundle, labeling all parts.

The **leaves** of corn have numerous **veins** (vascular bundles) running parallel to the long axis. Study a prepared slide of a cross section of a corn leaf showing (1) an outer, protective **cuticle;** (2) an **epidermis** on the upper and lower surfaces composed of one layer of cells with **stomata** and **guard cells** for the exchange of gases; (3) **photosynthetic tissue,** a mass of compactly arranged cells which contain **chloroplasts** for photosynthesis; (4) **veins** composed of phloem and xylem for conducting liquids; (5) **air spaces** beneath the stomata for the storage of gases.

DRAW an enlarged cross section of a corn leaf labeling all parts.

The **flowers** of corn are incomplete and are on different parts of the same plant. The **tassel** (male) at the tip of the stem consists of pollen-producing **stamens,** each with a stalklike **filament** at the tip of which is an enlarged pollen-forming **anther.**

DRAW male flowers (tassel) of corn labeled correctly.

The **pistils** (female) consist of a series of **ovaries** (future "kernels") arranged on the corn "ear." A long **style** ("silk") is attached to each **ovary,** and the **stigma** (tip of the style) is sticky to retain the pollen. A **pollen tube** for pollen conduction grows through the style to the ovary where fertilization occurs.

DRAW female flowers of corn labeled correctly.

A **grain of corn** is really a **fruit** (ripened ovary) and consists of (1) an outer **pericarp** beneath which is (2) the **seed coat,** (3) the **endosperm,** or stored food for (4) the developing **embryo** located in a depression near the tip of the **grain.**

DRAW a grain of corn, labeling all parts correctly.

Make a TABLE which summarizes the characteristics of (1) dicotyledonous plants and (2) monocotyledonous plans, including the following items for each: (a) number of cotyledons (embryonic seed leaves), (b) type of leaf venation, (c) number of flower parts, (d) arrangement of vascular bundles in the stems, (e) presence or absence of cambium, (f) whether the stems are usually woody or herbaceous, (g) typical examples of each.

5. Evaluation of collected data and information

Do the collected data and information tend to prove or disprove the hypotheses and problems? Give reasons why you say so. Were your studies sufficiently extensive and accurately made so as to give reliable, pertinent information? Are there instances where you made inaccurate observations or errors in interpretation? List specific ways whereby all such errors may be corrected.

6. Drawing logical conclusions based on data and facts obtained

RECORD the conclusions which you can draw from the logical interpretation of the information which you secured from your studies of angiospermous plants. Do these conclusions prove or disprove your hypotheses and problems? List ways whereby you might secure additional pertinent information and include specifically how this information may be used in connection with the solution of the problems. Can you draw any conclusions from your studies which were not suggested by the problems? List them specifically.

7. Rechecking all steps

Recheck all procedures which you followed in securing accurate information, especially those areas in which you may have made errors. Repeat all observations which may have given doubtful information. If desirable make additional studies of other angiosperms in order to secure additional, reliable, and pertinent information.

Biology of higher plants

1. Problems

How are roots of higher plants constructed so as to perform their various functions? How are roots protected as they are pushed forcibly through the soil? How are stems of higher plants constructed so as to perform their various functions? How are substances conducted upward and downward through stems? How are leaves constructed so as to perform their various functions? How does photosynthesis take place and what are the end products? How are flowers constructed and how do they assist in pollination and eventually in fertilization? Do all flowers necessarily possess petals in order to reproduce? How is a pollen tube developed in the pistil and for what purpose? Botanically speaking does the term fruit have the same meaning as that commonly applied in a fruit market? Do higher plants produce different kinds of fruits, and how are they derived and classified? How are materials absorbed and translocated (conducted) in higher plants? What theories are advanced to explain the rise of liquids in plants, especially high trees? How do green plants manufacture and store various types of foods? Do all plants respire? How do leaves fall at the end of a growing season by the process of abscission? In what ways are higher plants of great economic importance to man?

2. Preliminary observations and pertinent data and information

RECORD all accurate information which you may have which is pertinent to the solution of the problems. Include only such information which you know is true and pertinent to the solution of the problems.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable, pertinent, preliminary information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods for securing additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study such parts of your text which may give answers to some of the above questions as well as supply information for filling in the blanks on the following pages. Study preserved materials, living specimens, museum mounts, prepared slides, projected slides, and such other materials as suggested by the instructor.

5. Evaluation of collected data and information

Do the collected data and information tend to prove or disprove the hypotheses and problems? State specifically why you say so. Did you make all observations and interpretations carefully and accurately? List any instances where you may have made errors.

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BIOLOGY OF HIGHER PLANTS

A. Roots of higher plants

(1) Plant roots arise embryologically from the ______________ of the embryo.

(2) The basal part of the hypocotyl, called the ______________, forms the first or ____________ ____________ of the new plant.

(3) Primary roots may form many branches called ______________ roots.

(4) Two root systems of plants are called ______________ systems and ______________ (______________) root systems.

(5) Principal functions of roots include (a) ______________, (b) ______________, and (c) ______________.

(6) Sometimes roots perform specialized functions some of which are:

(a) ______________ (b) ______________

(c) ______________ (d) ______________

(e) ______________ (f) ______________

(g) ______________ (h) ______________

(7) Growing tips of roots are protected by ______________.

(8) Typical appendages which are slender extensions of the epidermal cells to increase the absorbing surface are called ____________ ____________.

B. Stems of higher plants

(1) Stems may be classified as (a) ______________ or (b) ______________.

(2) Herbaceous stems may be differentiated as follows:

Dicotyledonous stems	*Monocotyledonous stems*
(a) ______________	(a) ______________
(b) ______________	(b) ______________
(c) ______________	(c) ______________
(d) ______________	(d) ______________

(3) Principal functions of stems include (a) ______________ (b) ______________ (c) ______________.

(4) Substances are conducted upward in stems by ______________ tissues, and downward by the ______________ tissues.

(5) Substances are conducted horizontally in woody stems by ______________.

(6) In most herbaceous monocotyledonous stems there is no ______________ tissue between the phloem and xylem of the vascular bundles.

(7) In such dicotyledonous, woody stems as trees, through the activity of the cambium a new concentric layer of wood cells is added annually to the outside of the woody cylinder, thus forming so-called ____________ ____________.

(8) Certain parenchyma cells which elongate at right angles to the long axis of the woody stem are arranged in horizontal, ribbonlike bands and constitute the ______________, which is arranged like the spokes of a wheel.

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(9) A milky liquid, ______________, is produced by various plants and is the source of rubber.

(10) Certain underground stems do not have foliage-bearing abilities, and are short and thick so as to constitute a ______________, as in potato plants, Jerusalem artichokes, etc.

(11) The principal differences between most roots and stems include:

Roots	*Stems*
(a) ______________	(a) ______________
(b) ______________	(b) ______________
(c) ______________	(c) ______________
(d) ______________	(d) ______________
(e) ______________	(e) ______________
(f) ______________	(f) ______________
(g) ______________	(g) ______________.
Examples:	Examples:

C. Leaves of higher plants

(1) Leaves arise from the terminal, growing point of the ______________.

(2) Unlike stems leaves have no organized ______________ ______________ and thus stop growing when mature size is reached.

(3) The broad part of a leaf is called a ______________ which may be attached directly to a stem or most frequently by a stalklike ______________.

D. Flowers and reproduction of higher plants

(1) Flowers develop from ______________, some of which develop only flowers, whereas those of other plants produce both ______________ and ______________.

(2) Flower colors usually result from pigments called (a) ______________ or (b) ______________.

(3) When a flower consists of 4 floral organs (sepals, petals, stamens, and pistil) it is said to be ______________.

(4) The outermost, green protective floral organs are called ______________.

(5) The floral organs just inside the sepals are called ______________.

(6) All sepals together constitute the ______________, and all the petals constitute the ______________.

(7) A stamen (microsporophyll) is composed of an enlarged, pollen-producing ______________ at the tip of a stalklike ______________.

(8) A pistil is composed of a pollen-receiving ______________, a ______________ of greater or lesser length to conduct pollen to the enlarged ______________ at the base.

(9) The units of which a pistil is composed are called ______________ and they bear and enclose the ______________.

(10) An ovule is composed of an ______________ ______________ (______________), a ______________, and ______________ (coverings).

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(11) An ovule, after fertilization, matures and develops into a ______________.

(12) Within the microsporangium (anther sac or pollen sac) each diploid (2N) microspore mother cell produces 4 monoploid (haploid) (N) ______________ (__________ __________).

(13) When microspores are produced the number of chromosomes is reduced from the diploid (2N) number to the monoploid (haploid) (N) number by a process called ______________.

(14) Before the pollen is shed the microspore nucleus divides to form a __________ __________ and a __________ __________.

(15) If pollen lights on the stigma of a proper plant a __________ __________ is formed which extends through the style to the embryo sac (megagametophyte) in the ovule.

(16) By the time the generative nucleus passes through the pollen tube it has divided into 2 ______________ (__________, or __________).

(17) Within the megasporangium (nucellus) each diploid (2N) megaspore mother cell produces 4 monoploid (haploid) (N) ______________.

(18) When megaspores are produced, the number of chromosomes is reduced from the diploid (2N) number to the monploid (N) number by a process called ______________.

(19) At the micropyle end of the embryo sac are 2 nonfunctional cells known as ______________ cells.

(20) At the end of the embryo sac opposite the micropyle are 3 nonfunctional cells known as ______________ cells, which are vestiges of the vegetative tissues of the megagametophyte.

(21) In the center of the embryo sac and resulting from previous fusion of 2 polar nuclei is the ______________ nucleus.

(22) The pollen tube usually enters the ovule through a small opening called the ______________.

(23) In so-called double fertilization one sperm (N) fuses with an egg (N) to form a ______________ (2N), which eventually forms an embryo. The other sperm (N) fuses with the endosperm nucleus (2N) to form ______________ tissue (3N).

(24) The fusion of a sperm with an egg takes place by a process called ______________.

(25) Certain flowers produce a sweet substance in organs known as ______________.

E. Fruits and seeds of higher plants

(1) After fertilization occurs a mature (ripened) ovary of a flower together with its seed (and sometimes adjacent parts which may be associated with it) develops into a ______________.

(2) After fertilizations an ovary is composed of a thickened ovary wall called the ______________ and one or more immature seeds known as ______________, which develop into mature seeds.

(3) The pericarp is derived from one or more ______________ which are modified leaves called megasporophylls.

(4) The responses of flowers in their attempts to produce fruit seem to be associated with a growth hormone called ______________.

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F. Kinds of fruits of higher plants

(1) As an ovary matures into a fruit its wall, the pericarp, may thicken and be differentiated into layers of tissues: (a) an outer __________, (b) a middle __________, and (c) an inner __________.

(2) Fruits may be classified as (a) __________, (b) __________, or (c) __________.

(3) Fruits derived from one mature ovary, plus in some species such adherent parts as sepals, stamens, etc., are known as __________ fruits.

(4) When the mature ovary wall (pericarp) of a simple fruit is paperlike, leathery, or woody, it is known as a __________ fruit.

(5) When simple, dry fruits open along definite seams or at definite points and may contain several to many seeds, they are called __________ fruits.

(6) Three kinds of simple, dry, dehiscent fruits with examples of each include:

(a) ______________________

(b) ______________________

(c) ______________________

(7) When simple, dry fruits do not split at definite seams or points and usually contain one or two seeds, they are called __________ fruits.

(8) Four kinds of simple, dry, indehiscent fruits with examples of each include:

(a) ______________________

(b) ______________________

(c) ______________________

(d) ______________________

(9) When the mature ovary wall (or some part of it) is filled with sap, the fruit is said to be __________.

(10) Fleshy fruits may be classified as (a) __________ __________, (b) __________ __________, (c) __________, (d) __________.

(11) When a fruit develops from a cluster of several to many ripened ovaries produced by one flower and borne on the same basal receptacle (axis of flower stalk bearing floral organs), it is known as an __________ fruit.

(12) When a fruit is formed from a cluster of several to many ripened ovaries produced by several flowers associated together closely on the same inflorescence rather than from a single flower, such a fruit is known as a __________(__________) fruit.

G. Absorption and translocation (conduction) of materials

(1) The process whereby solid particles, chiefly colloidal, absorb liquids and increase in volume (swell) is called __________.

(2) The diffusion of water through a differentially permeable membrane from a region of high water concentration to a region of lower water concentration is called __________.

(3) A process called __________ is one in which molecules of a substance spread through all the space which they can reach, going from the place where the molecules are more abundant to places where they are less abundant.

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(4) The conduction of liquids and dissolved materials through specialized tissues is known by the scientific name of ______________.

(5) Water and dissolved material are conducted upwards largely by ______________ tissues.

(6) Some of the principal functions of water in plants include: (a) ______________

(b) ______________ (c) ______________

(d) ______________ (e) ______________.

(7) Theories proposed to account for the ascent of liquids in stems include:

(a) ______________ (b) ______________

(c) ______________ (d) ______________.

H. Transpiration and guttation

(1) The loss of water vapor from aerial parts of plants, particularly through the stomata of leaves, is called ______________.

(2) The exudation of water from plants, usually in the form of drops, is called ______________.

(3) Usually stomata are more numerous on the ______________ surface of leaves.

(4) The closing, opening, and changes in size of stomatal openings are caused by changes in the surrounding, paired ______________ cells.

(5) The internal water pressure in cells is called ______________.

(6) When guard cells are well filled with water, the stomata ______________, whereas decreased water content causes them to close.

(7) Some of the more influential environmental factors affecting the transpiration rate include:

(a) ______________ (b) ______________ (c) ______________

(d) ______________ (e) ______________.

I. Manufacture and storage of foods

(1) Most life depends on the manufacture of foods by chlorophyll-bearing plants through the process of ______________.

(2) The chlorophyll transforms ______________ (______________) energy into ______________ (______________) energy, to be stored in the manufactured food.

(3) Photosynthesis occurs principally in green bodies called ______________ located in the inner, mesophyll tissues of leaves.

(4) Chlorophyll is concentrated in small bodies called ______________.

(5) In higher plants there are two types of chlorophyll, known as ______________ and ______________.

(6) The two chlorophylls differ from each other in the two elements ______________ and ______________.

(7) A deficiency in the element ______________ causes a failure of normal chlorophyll development, producing a pale, greenish yellow plant.

(8) Chlorophyll is somewhat similar chemically to the red pigment of blood, except the latter contains ______________ instead of magnesium.

(9) In the process of photosynthesis in higher plants, ______________ is produced and ______________ is given off as a by-product.

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(10) Energy necessary for photosynthesis is supplied by ______________, either solar or artificial.

(11) When white light is passed through a prism, several region of different colors and wave lengths, called the ________ ________, are revealed.

(12) Carbohydrates and fats contain the three chemical elements: (a) ______________, (b) ______________, and (c) ______________.

(13) The building blocks used in constructing proteins are called ______________ acids.

J. Respiration and digestion

(1) In the chemical oxidative process called ______________, all living protoplasm breaks down certain organic substances with the release of energy to be used for various activities of the protoplasm.

(2) The term ______________ is applied to the sum total of the chemical changes in living protoplasm.

(3) Changes which result in constructive or building-up processes are called ______________, whereas destructive or tearing-down processes are called ______________.

(4) The chief differences between respiration and photosynthesis include:

Respiration	*Photosynthesis*
(a) ______________	(a) ______________
(b) ______________	(b) ______________
(c) ______________	(c) ______________
(d) ______________	(d) ______________
(e) ______________	(e) ______________
(f) ______________	(f) ______________
(g) ______________	(g) ______________

(5) The capacity to do work may be defined as ______________.

(6) Perhaps all chemical reactions within living cells are controlled by organic catalysts called ______________.

(7) When a sufficient supply of free oxygen is available, respiration is considered as ______________ respiration.

(8) Under certain conditions respiration may occur in the absence of free oxygen and is called ______________ respiration.

(9) Both types of respiration are controlled by specific ______________ and release energy.

(10) The change of foods into a soluble, diffusible form through the action of enzymes is called ______________.

(11) The digestive activity in plants whereby starch is changed into sugar is accomplished through the catalytic activity of a specific enzyme called ______________.

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(12) Nearly all digestive enzymes change a complex compound into one or more simpler compounds through a reaction with water, which is known as ____________.

(13) Proteins are hydrolyzed into amino acids by enzymes known collectively as ____________.

K. Abscission

(1) The separation of plant parts such as leaves, stems, flowers, fruits, etc., usually by the natural dissolution of certain cell walls, is known as ____________.

(2) The leaves of deciduous plants fall at the end of their growing season because specialized parenchyma cells at the base of the leaf petiole become thick-walled and differentiated to form an ____________ layer.

(3) Substances in the cell walls of the abscission layer and known as ____________ are dissolved through the action of enzymes, partially detaching the petiole from the stem with only the vascular bundles remaining to hold the leaf until it falls eventually.

(4) A layer of ____________ tissue develops at the petiole base for protection of the exposed tissues.

(5) Abscission is controlled by special chemicals called ____________.

(6) Two common plant hormones (growth substances) are chemicals by the name of ____________ and ____________.

(7) Among probable causes of abscission are: (a) ____________, (b) ____________, and (c) ____________.

L. Economic importance of certain plants

(Look up answers to the following in your text and other available sources)

(1) Some of the important fuels produced by plants include the following:

(2) Some of the important coloring matters (dyes) produced by plants include:

(3) Some of the important fibers produced by plants including the following:

(4) Some of the beverages produced by plants include the following:

(5) Some medicines and poisons produced by plants include the following:

6. Drawing logical conclusions based on data and facts obtained

RECORD the conclusions which you can draw from the logical interpretation of the information which you collected from your studies. Do these conclusions prove or contradict your hypotheses and answers to the questions and problems? List specific conclusions which you can draw from your studies which may not have a direct bearing on the stated problems. Are your conclusions valid? Why do you say so?

7. Rechecking all steps

Recheck all your information to see that it is accurate and that you made the proper interpretation in each instance. Recheck all instances where you may have made errors in observation or interpretation and reconsider your conclusions in the light of your newly evaluated information. List additional sources of pertinent information and if time permits make additional studies.

Kinds of fruits

1. Problems

Are fruits when considered in the biological sense the same as when we purchase them at the market? Are fruits really the ripened (matured) ovaries of flowers? May the pericarp (wall of the mature fruit) be differentiated into (1) an outer exocarp, (2) a middle mesocarp, and (3) an inner endocarp? Are these three layers of tissues of the same thickness, structure, and texture in all fruits? May fruits be classified on the basis of their structure and of the number of ovaries which compose them? In so-called accessory fruits may flower parts other than the ovaries adhere to or enclose the mature ovaries? Is a classification of fruits into (1) simple, (2) aggregate, and (3) multiple (compound) fruits logical and scientific? How can simple fruits be divided into (1) dry and (2) fleshy fruits? May multiple (compound) fruits be formed from a cluster of several to many ovaries produced by several flowers associated together closely?

2. Preliminary observations and pertinent data and information

Do you have any preliminary information which is accurate and which pertains specifically to the proving or disproving of the problems? If so RECORD it accurately.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable preliminary information can you formulate hypotheses from which you may work in the solution of the problems? How may additional pertinent information be secured? (Be specific in your suggested methods of investigation.)

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

If you are not completely familiar with the parts of a flower review them, especially those pertaining to the ovary. Study the characteristics of the various kinds of fruits and carefully observe such fruits as are supplied by the instructor. RECORD the traits and examples on the page supplied. MEMORIZE the traits and examples as you record them. Make DRAWINGS of certain kinds to remember them.

5. Evaluation of collected information and data

Does the information which you collected prove or disprove the hypotheses? Have you studied a sufficient number of representative types of each kind of fruit? Can you think of additional examples for each of the several kinds of fruit? Would it be desirable to attempt to classify them correctly without actual observation of them?

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KINDS OF FRUITS

	Characteristics	Examples
I. Simple fruits		
A. *Dry fruits*		
1. Dehiscent fruits		
(a) Legume		
(b) Follicle		
(c) Capsule		
2. Indehiscent fruit		
(a) Achene		
(b) Grain (caryopsis)		
(c) Samara (key or wing fruit)		
(d) True nut		
B. *Fleshy fruits*		
1. True berry		
2. False berry		
3. Drupe ("stone fruit")		
4. Pome		
II. Aggregate fruits		
III. Multiple fruits (compound)		

6. Drawing logical conclusions based on facts and data obtained

What conclusions can you draw from the information which you secured? Do these conclusions solve the problems? Why? Did you make all observations carefully? Why is this important? List ways in which additional, pertinent information might be secured.

7. Rechecking all steps

Recheck any specimens in which you believe you may have made errors in observation or interpretation. If you are not sure that you observed accurately repeat such observations carefully and fully so that your information is as correct as possible.

Part Three

ANIMAL BIOLOGY

21
The animal kingdom—major groups of animals

1. Problems

Do the thousands of kinds of animals possess traits whereby they may be classified in the form of a key? By the accurate use of a proper key and the correct interpretation of certain traits of an unknown animal is it possible to identify such an unknown animal?

2. Preliminary observations and pertinent data and information

RECORD all the accurate preliminary information which you have concerning these problems. Be sure your information is accurate and pertinent.

3. Formulation of hypotheses and determination of methods of investigation

From your preliminary information state hypotheses from which you may work toward the solution of these problems. Are these hypotheses plausible in the light of your preliminary information? What methods of investigation do you propose whereby you may be able to secure additional information and data from which you may prove or disprove the hypotheses?

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Make careful studies of labeled specimens of various types of animals as supplied by the instructor. By referring to the proper places in the accompanying Simple Key for Classifying the Major Groups of Animals, observe carefully all the traits listed which characterize each major group. By following the key trace your known, labeled animals to the correct place in the key. Be sure you are familiar with each detailed trait because you will be required to identify unknown animals by the correct interpretation of these traits. You may need some assistance from the instructor concerning certain points.

How to use a key. Space does not permit the presentation of a complete and detailed key, but this simple one will give you practice in the use of more detailed keys later. In using the key, start with **I.** If the descriptive traits listed under **I** apply to the specimen you are studying, then you have started to find out the group to which your specimen belongs. NOTE: Always check the opposite or alternative traits (in this case those under **II,** to ascertain if the traits described under **II** might fit your specimen).

If traits under **I** do not apply, proceed to **II** and consider traits under both **A** and **AA.** If traits under **AA** apply, then proceed to **B** or **BB,** etc. Continue this process until you have traced your specimen down to the correct major group of animals.

After ascertaining the group to which you think your specimen belongs, repeat the entire procedure again (several times) until you are certain that you are correct in your interpretations. Any error made will cause you to fail in identifying the specimen correctly. Learn to observe carefully and to do things accurately. This may take time and patience, but it will pay big dividends on your investment of energy and time.

Identify a number of unknown animals by the use of the key. Identify these unknowns by numbers, giving the correct group of animals to which you believe each belongs. Record the number of each unknown and the group name to which each belongs.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive to form a basis for proving or disproving them? Why do you say so? Explain any instances where you may have made erroneous interpretations, including any explanations why you think

SIMPLE KEY FOR CLASSIFYING THE MAJOR GROUPS OF ANIMALS*

I Single-celled (acellular) or aggregates of similar cells (colonies)	**Protozoa**
II Multicellular animals, with cells differentiated into tissues or into tissues and organs	
A—Without digestive cavity; body wall with pores and canals; radial symmetry (some species) and asymmetry (some species)	**Porifera**
AA—Digestive cavity present (absent in a few species)	
B—Body wall formed of 2 cell layers (diploblastic); unbranched tentacles around the mouth; internal gastrovascular cavity, called coelenteron, without anus; radial symmetry (usually)	**Coelenterata (Cnidaria)**
BB—Body formed of 3 embryonic cell layers (ectoderm, mesoderm, entoderm) (triploblastic)	
C—No cavity between body wall and digestive tract	
D—Biradial symmetry (radial arrangement of parts into 2 sides) .	**Ctenophora**
DD—Bilateral symmetry (dual arrangement of parts); body wormlike and flattened; gastrovascular cavity without anus	**Platyhelminthes**
CC—False cavity (pseudocoel) which is not formed within mesoderm layer; true alimentary tract; body usually cylindrical and pointed at both ends	**Aschelminthes (Nemathelminthes)**
CCC—True body cavity (coelom) formed within mesoderm layer and lined with mesodermal epithelium	
D—Body not formed by linear series of segments	
E—Bilateral symmetry (usually) or in part spirally coiled; usually a limy shell	**Mollusca**
EE—Radial symmetry (in adults); body parts in fives or multiples of fives; outer covering spiny	**Echinodermata**
DD—Body formed by linear series of segments	
E—No prominent skeletal structures	**Annelida**
EE—Skeletal structures	
F—External horny skeleton (chitin); paired, jointed appendages	**Arthropoda**
FF—Internal skeleton (cartilage, bone); dorsal nervous system; pharyngeal clefts ("gill slits") at some stage of life cycle	**Chordata**

*A more detailed classification key is given in Appendix 2.

you may have done so. Can such a simple key be followed easily in the complete identification of unknowns? Would a longer, more detailed key be of greater value? In order to emphasize simplicity in a key must we sacrifice many detailed considerations which might be helpful in an easier and more accurate system of classification and identification? Did you do an accurate job of identifying all of the animal unknowns? In which groups did you have greatest difficulty? Can you give any logical reasons for this?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the information which you secured? Do these conclusions prove or disprove your hypotheses and the problems? If not, what do you suggest in order to do so? Can you draw any conclusions from your studies which were not necessarily connected with the problems? If so, state them accurately.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure your information. Recheck particularly those points which you think may have resulted in errors. How many times did you repeat your attempt to properly identify each unknown? Do you think this was a sufficient number of times to guarantee accuracy? How many times must a thing be done or observed in order to guarantee accuracy?

Cellular organization of animals (tissues and organs)

1. Problems

Are all animals composed of one or more cells, and in higher animals are these cells organized into tissues and organs? Are there special types of animal tissues, each with its special kind of construction and functions?

2. Preliminary observations and pertinent data and information

RECORD all the accurate, preliminary information which you may have concerning these problems. Be sure your information is accurate and pertains to the problems.

3. Formulation of hypotheses and determination of methods of investigation

From your preliminary information state hypotheses from which you may work in the solution of the problems. Are these hypotheses plausible in the light of your limited information? Suggest methods of investigation whereby you may be able to secure additional information from which you may prove or disprove the hypotheses.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Would a careful study of several, representative animal tissues supply additional, pertinent information? How many tissues should be studied in order to secure a sufficiently extensive amount of information? In general are all animal tissues constructed in a similar way? In order to secure additional data make careful studies of prepared slides of the following tissues (or similar ones as suggested by the instructor).

EPITHELIAL TISSUES

Squamous (pavement). This tissue, which covers **external surfaces** and lines **internal** cavities, is composed of **flat cells** which are arranged like pavement stones. There may be only one layer of cells (simple) or more than one layer (stratified).

DRAW squamous epithelial tissue, labeled correctly.

Columnar. This tissue lines the intestine and stomach and is composed of **column-shaped cells,** often with tapering ends next to the underlying tissues.

DRAW columnar epithelial tissue, labeled correctly.

CONNECTIVE (SUPPORTIVE) TISSUES

Areolar. This widely distributed tissue is composed of numerous, wavy, **white fibers (collagenous)** and a few **yellow fibers (elastic)** which may be **branched** to form a loose **network.**

DRAW areolar connective tissue, labeled correctly.

Adipose. This special type of areolar tissue has the **intercellular spaces** filled with fat which is contained in hollow, **"signet-ring" cells,** with a **nucleus** at one side of the cell.

DRAW adipose connective tissue, labeled correctly.

Hyaline cartilage. This consists of a clear, flexible, ground substance, the **matrix,** with scattered **lacunae in** which are one or more rounded **cartilage cells.**

DRAW hyaline cartilage tissue, labeled correctly.

Bone. The units of bone construction, known as **haversian systems,** consist of a **central canal** (containing an artery, vein, and nerve); numerous **lamellae** made of layers of **bony plates** so arranged concentrically as to form circles or ovals around the central canal; enlarged spaces, called **lacunae,** which are associated with the lamellae and contain irregularly shaped **bone cells;** tiny canal-like **canaliculi** which radiate from the lacunae and connect lacunae with each other and with the central canal; a hard, limy **matrix** secreted by the bone cells.

DRAW bone tissue (to show a haversian system), labeled correctly.

BLOOD (VASCULAR) TISSUES

This tissue is composed of a liquid **plasma** in which are suspended **red blood corpuscles (erythrocytes), white blood corpuscles (leukocytes),** and **blood platelets.** In human blood the **erythrocytes** are biconcave discs (7μ in diameter) **without a nucleus** (when mature), and are much more numerous than the **nucleated leukocytes.** The latter are of various types and their sizes vary (7 to 14μ). The **platelets** are small (3μ), irregular, **nonnucleated** masses of protoplasm.

DRAW the various types of blood corpuscles and some platelets, properly labeled.

MUSCULAR (CONTRACTILE) TISSUES

Skeletal (striated). These muscles are associated with the skeleton and are composed of **cylinder-shaped cells,** each with **several nuclei per cell.** They have internal fiberlike, contractile **myofibrils** and alternate **dark** and **light bands,** thus giving them a **striated** (striped) appearance.

DRAW a skeletal (striated) muscle cell, labeled correctly.

Visceral (unstriated or smooth). These muscles occur in the walls of the **viscera** (internal organs), and the cells are **long, spindle-shaped,** and with **one central nucleus.** The internal **myofibrils are not striated.**

DRAW several unstriated muscle cells, labeled correctly.

NERVOUS TISSUES

These tissues are composed of **neurons** (nerve cells), each with a **nucleus** and processes which arise from the cell body. The processes are of two kinds: branched **dendrons (dendrites)** to carry impulses to the neuron and **axons** to carry impulses away from the neuron. The two processes vary with the different types of nervous tissue. Within the neurons are **neurofibrils,** probably for impulse conduction. **Nissl's granules** in the cytoplasm probably perform a nutritive function.

DRAW several types of neurons with all parts labeled correctly.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Is the information sufficiently extensive? Why do you say so? Did you study each tissue carefully and did it possess the characteristics listed for it? Of the tissues studied did you find any which did not quite fit the brief characteristics as described? Might this be due to variations in the tissues studied or to errors in your observations and interpretations? Although you did not study all of the various types of animal tissues, do you think a study of representative types of all kinds would give additional information?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the information secured? Do they prove or disprove the hypotheses and problems? If you made errors, where did you make them and why? Did you repeat your observations sufficiently to be accurate?

7. Rechecking all steps

Did you recheck all procedures carefully several times to eliminate the possibilities of errors in observation and interpretation? Did later observations and interpretations differ from your original ones? If so, what explanations do you have for this?

Mitotic cell division (mitosis) in animals

1. Problems

Do animal cells undergo a rather complex process whereby a cell divides to form two new cells, and as a consequence may such phenomena as growth, development, repair, and the transmission of hereditary traits take place?

2. Preliminary observations and pertinent data and information

RECORD any preliminary information you may have which is accurate and pertains specifically to the proving or disproving of the problems.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable, preliminary information formulate hypotheses from which you may work toward the solution of the problems. How and where might you secure additional information concerning these problems?

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study a prepared slide of the blastula stage of the whitefish embryo or similar cells, as suggested by the instructor. Carefully identify each characteristic described under each stage. As you study each stage move the slide until you find a typical example of that stage. Attempt to identify all important parts in each stage, making careful observations. Do you find some cells which do not quite fit the descriptions given? Can you give any reasons for this? Have all the stages been described or have some of the intermediate steps been omitted for the sake of brevity? If any structures are not visible, what explanations can you give for this fact? Why must stained sections of incomplete cells be studied? What significance might this play in explaining the absence of certain structures? What would be some of the difficulties encountered if the process of cell division were to be observed in living, unstained cells? What role might slow motion movies play in such studies? Do you think that cells in other animal tissues would show stages similar (in a general way) to those which you studied? Do certain cells undergo a division process in all animal tissues at all times? Why? Would old tissues be a satisfactory source of data? Why?

Interphase. This stage occurs before the phases of actual division begin and in it the **nucleus** shows fine, coiled, threadlike **chromonemata** and contains deeply stained **chromatin.** At times the threads form a netlike **reticulum.** A **nucleolus** is present in the **nucleus,** and a **nuclear membrane** separates the **nucleus** from the **cytoplasm.**

DRAW an interphase stage with all parts labeled correctly.

Prophase. The network of nuclear materials condenses into coiled **chromatin threads.** The latter are double and eventually break (crosswise) into a specific number of definite bodies, the **chromosomes** (each composed of a pair of **chromatids**). The chromatin threads thicken and shorten and contain minute bodies called **chromomeres,** which give the appearance of a string of beads. Each chromosome has a specific, clear area, the **centromere (kinetochore),** which may assist in the orientation and division of the chromosomes.

Outside the nucleus the **centrosome (central body)** is composed of a granular **centriole** and is surrounded by a sphere of cytoplasm, the **centrosphere.** The centrosome divides and one centriole goes to each new centrosome. The newly formed centrosomes move apart around the nucleus to positions ("poles") opposite each other. Fine threadlike aster rays radiate from the centrosomes to form the **asters.** Fine fibers connect the two migrating centrosomes and form a **mitotic spindle** which increases in size progessively as the centrosomes migrate farther apart. When the centrosomes have reached opposite "poles" the spindle is broadest near the center of the cell, at the **equatorial plate,** and tapers at either end toward the centrosomes. The thin, **nuclear membrane and the nucleolus disappear.** In late prophase the chromosomes move toward the equatorial plate.

DRAW a prophase stage will all parts labeled correctly.

Metaphase. In this stage the chromosomes are present at the equator of the spindle. Each chromosome attaches itself to a **chromosomal fiber of the spindle** by means of its **centromere.** Each **chromosome now divides lengthwise** and each contains a series of coiled spirals.

DRAW a metaphase stage will all parts labeled correctly.

Anaphase. The pair of **chromatids** which constitute each chromosome separate lengthwise, starting at the **centromere.** This longitudinal splitting divides the **genes** (carriers of hereditary materials) so that each newly formed chromosome will have inheritance abilities identical to its partner. The centromeres are attached to the spindle and the newly formed **daughter chromosomes** move along the spindle to opposite poles. This phenomenon may be observed in prepared slides as a progressive series of stages.

DRAW an anaphase stage, labeled correctly.

Telophase. After the chromosomes reach opposite poles they elongate and the coils of the chromonemata loosen and gradually assume a **threadlike network.** The **spindles and asters disappear,** but the **centrosomes persist,** one with each daughter nucleus. A **nuclear membrane re-forms** and the **nucleolus reappears.**

The **cytoplasm** divides by forming a furrow, or indentation, in the **plasma membrane** (at the equatorial region), and this deepens gradually so as to divide the cell eventually. The telophase is followed by an interphase stage again.

DRAW a telophase stage, labeled correctly.

When studying a slide, it will be observed that there are cells which are undergoing cell division but whose characteristics do not quite fit the phases described above. Only a few of the more important stages are described and there are many stages for each phase which have been omitted for the sake of brevity.

5. Evaluation of collected data and information

Does the information which you collected prove or disprove the hypotheses and problems? Would it be desirable to study the division of cells in additional animals? Why? Do studies of the divisions of cells in animals assist in the explanation of such phenomena as growth, repair, development, and the transmission of hereditary traits? If so, give accurate explanations.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the information which you secured? Do these conclusions prove or disprove the hypotheses and problems? What additional conclusions can you draw which may not be directly associated with the stated problems? Could abnormal cell divisions be associated with certain types of diseases? What kinds of diseases might be associated with such abnormalities? List ways in which additional, pertinent information might be secured.

7. Rechecking all steps

Recheck everything which you did, especially in instances where you may have made errors in observation or interpretation. If you were not certain that you saw certain structures clearly, study the slide until you do. Have your conclusions been changed as a result of your newly observed and interpreted information?

Meiotic cell division (meiosis) in animals

1. Problems

Because body (somatic) cells of higher animals possess a double or diploid (2N) number of chromosomes, how can gametes (sex cells) be formed which have a monoploid or haploid (N) number? How and when is this process of reduction division (meiosis) accomplished in higher animals? Why is it necessary to reduce the number of chromosomes before a sperm and egg unite? Does the process of meiosis follow somewhat the same stages (prophase, metaphase, anaphase, and telophase) as mitotic cell division (mitosis)? What are the chief differences between meiosis and mitosis? If reduction division occurs as gametes are formed and matured, might a study of reproductive organs of certain animals, at the proper time, be desirable to observe this phenomenon? Of what significance is reduction division in heredity? How are the formations of nonfertilizable polar bodies during the production of eggs (oögenesis) of importance in heredity? Of what significance is the process of synapsis, in which homologous pairs of chromosomes (homologues) lie side by side and may twist around each other? Might there be a mutual crossover of parts of homologues (and their genes) during synapsis, with an effect on the heredity of certain traits?

2. Preliminary observations and pertinent information and data

RECORD all reliable information which pertains to the problems and which may tend to prove or disprove them. Include only accurate, pertinent information.

3. Formulation of hypotheses and determination of methods of investigation

From the preliminary information which pertains to the problems, state hypotheses from which you may work toward the solution of the problems. RECORD them as well as specific methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent information

Meiosis in higher animals can be illustrated during the formation of gametes (gametogenesis) in the roundworm (Ascaris).* The production of sperms is called **spermatogenesis** and the production of eggs (ova) is called **oögenesis.** Gametogenesis is essentially the same in both male and female but there are differences, especially those involving unequal division of cytoplasm in the female. When cells divide in gametogenesis, the last 2 cell divisions in both spermatogenesis and oögenesis are called **maturation divisions** or **meiotic cell division (meiosis).** Meiosis consists essentially of 2 nuclear divisions whereas the chromosomes divide only once, eventually forming 4 cells whose nuclei contain the monoploid (haploid) number of chromosomes. These 2 divisions are called the **first meiotic division** (Division I) and the

******Ascaris megalocephala* **is now known as** ***Parascaris equorum,*** **and the name Ascaris is used as a common name.**

second meiotic division (Division II). In each division there are the same stages: prophase, metaphase, anaphase, and telophase. This reduction in the chromosome number from the diploid (2N) to the monoploid (N) number is called meiosis.

The stages of meiotic cell division (meiosis) in plants are considered in some detail elsewhere and should be reviewed at this time. Meiosis is essentially the same in fungi, flowering plants, insects, worms, and man. After the sequence of stages and their specific characteristics are well in mind, the following observations should be made with great care.

Study a prepared slide of a thin section of the female reproductive system of the roundworm (Ascaris), in which female gametes are in various stages of maturation. Also study demonstration materials, color transparencies, models, charts, illustrations, etc.

Identify an **egg** with its **nucleus** and **without a shell.** Identify **sperms** which appear as **small, tailless, triangular cells** with a **dark nucleus and a small amount of cytoplasm.** The sperms are not formed here but are transferred from the male.

Identify an **egg into which a sperm has entered.**

Identify an **egg with 2 cross-shaped (X-shaped) bodies** near the edge of the cell. The maturing egg with its thick shell at this stage is called a **primary oöcyte,** and the X-shaped bodies are **paired, duplicated chromosomes** collectively called a **tetrad** (Gr. *tetra,* four). Can you observe a **spindle** associated with these chromosomes? Such a cell may contain a **sperm pronucleus,** and if so, include it in your drawing.

DRAW a **primary oöcyte** showing all structures labeled correctly.

When a primary oöcyte divides in meiotic division I, one cell, called a **secondary oöcyte, gets most of the cytoplasm** and the other cell, called the **first polar body, gets less cytoplasm and is nonfunctional,** being reabsorbed eventually. Find such a cell in which two of the paired, duplicated chromosomes are kept within the egg and the other two are extruded from the egg and placed in the first polar body. Even though the polar body received less cytoplasm it did receive one member of each pair of homologous chromosomes. When the polar bodies are reabsorbed, the contained chromosomes and their genes are lost. Of what significance is this in heredity?

DRAW a stage in which the first polar body is being formed, labeling correctly.

Study a **secondary oöcyte** in which there are **4 dotlike chromosomes on the spindles** and a **polar body outside the cell** and against the fertilization membrane.

DRAW such a cell with chromosomes on the spindle and a polar body outside the cell. This is equational division (separation of duplicated chromatids).

Find a later stage with a **second polar body** extruded from the egg nucleus.

DRAW a secondary oöcyte showing the formation of a second polar body. Label correctly.

The female gamete is now mature and unites with the male gamete which was mature before it entered the egg. Both male and female pronuclei (nuclei of the gametes) appear as 2 dark spherical bodies, the chromatin becomes diffuse, and the nuclear membranes re-form. These are called **pronuclei,** since they differ from the somatic nuclei in having only one-half as many chromosomes.

The **first cleavage of the fertilized** egg can now occur by **mitotic cell division (mitosis),** which process will continue throughout the development of the embryo and adult.

The details of **spermatogenesis** are not as easily observed as they are in oögenesis. The changes in the nuclei are identical to those in oögenesis, but the cytoplasm is divided equally in both divisions, resulting in 4 equal spermatids (forerunners of sperms) from each primary spermatocyte originally, whereas in oögenesis the cytoplasm is divided unequally between the primary oöcyte and the first polar body and between the secondary oöcyte and the second polar body.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Why do you say so? Were your studies sufficiently representative and extensive to prove or disprove them? Explain instances where you may have made errors in observations or interpretations, including reasons why you may have made them.

6. Drawing logical conclusions based on data and information obtained

What conclusions can you draw from the logical interpretation of the collected information? Draw additional conclusions which may not be directly associated with the specific problems as stated. Do not draw conclusions which are not justified by the collected information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed, especially those in which you may have made errors. Repeat any observations and interpretations which you think were erroneous. **Reread the detailed descriptions of the stages of meiosis** so as to ascertain if you may have missed some important points. **Be sure that you can describe the entire process,** including the details of each stage as well as the important phenomena which occur. Do your repeated observations and interpretations change your original conclusions?

Unicellular (acellular) animals (phylum Protozoa)

1. Problems

How are single-celled (acellular) animals constructed so that they are able to perform all the functions necessary for living? Do protozoans possess noncellular organelles for performing certain functions? Do various protozoans in the adult stages possess different methods of locomotion? Do some protozoans possess certain traits which are also characteristic of lower plants? Might certain types of protozoans be called "plant-animals"? Do certain protozoans possess sexual methods of reproduction? Are certain protozoans constructed in the form of a colony? Do certain types of protozoans produce diseases?

2. Preliminary observations and pertinent data and information

RECORD any reliable, pertinent information which you may have which tends to prove or disprove the above problems. Include only accurate information which pertains to the problems.

3. Formulation of hypotheses and determination of methods of investigation

From the preliminary information which pertains to the problems, state hypotheses from which you may work in the solution of the problems. RECORD methods of investigation which will supply additional, reliable information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study living specimens, prepared slides, and projected slides of such protozoans as suggested by the instructor. In some instances life cycles may be studied to supply additional information. Demonstrations may be substituted for individual work as suggested by the instructor.

Amoeba (class Sarcodina)

This fresh-water protozoan is about 500μ (0.5 mm.) long and is an **irregular, colorless, jellylike, granular mass** which locomotes by forming temporary, fingerlike **pseudopods.** The living protoplasm with its contained **granules** and **vacuoles** displays a **flowing (streaming) movement.** A disk-shaped **nucleus** is present.

The pseudopods surround food which is digested in **food vacuoles** through the action of **digestive enzymes.** A spheroid organelle, the **contractile vacuole,** slowly enlarges by collecting wastes and then contracts to expel them. The *Amoeba* reproduces asexually by **binary fission** forming two **daughter amebas.**

Study a prepared, stained slide of *Amoeba.*

With a clean pipette place a drop of a living culture of *Amoeba* on a clean slide and cover carefully with a clean cover slip. Study the animals with patience because they are not easily observed in the living unstained condition.

DRAW an *Amoeba* (enlarged) with all parts labeled correctly.

Peranema (class Mastigophora) (Flagellata)

This **unicellular, mononucleated, flagellated** protozoan is found in stagnant water, hay infusions, etc. It is about 100μ ($\frac{1}{250}$ of an inch) long. The posterior end is blunt but tapers anteriorly and contains a long anterior **flagellum** which vibrates as the animal locomotes. There is also a smaller less conspicuous flagellum. When not swimming, the body form may assume many different, temporary shapes, suggesting that its **cell membrane** is flexible. It lacks chlorophyll so must ingest other minute organisms or absorb organic materials. The **cytosome (pharynx)** ingests solid materials. A **contractile vacuole** at the base of the pharynx excretes wastes.

With a clean pipette place a drop of *Peranema* culture on a clean slide, adding a clean coverslip. Observe and DRAW, showing all structures labeled correctly.

Noctiluca (class Mastigophora) (Flagellata)

This **spherical, marine** protozoan has a **cell membrane** which is **grooved.** The animal is larger than 100μ ($\frac{1}{250}$ of an inch) and contains **two flagella of unequal size.** The cytoplasm contains many **vacuoles** and color-bearing **chromatophores** (Gr. *chroma*, color; *pherein*, to bear). If these colored bodies are numerous the animals may impart a reddish orange tinge to water in daylight. A glowing, bluish green luminescence (without heat) may be caused in the sea at night by *Noctiluca.*

With a clean pipette place a drop of *Noctiluca* culture on a clean slide and add a clean coverslip. Observe and DRAW, showing all parts labeled correctly.

Paramecium (class Infusoria) (Ciliata)

This **fresh-water, slipper-shaped** protozoan is about 0.2 mm. long. On one side a depression called the **oral groove** runs obliquely backward to the **mouth.** One or two **nuclei** may be present (depending on the species).

Covering the external surface is a clear **pellicle (cuticle)** which is divided by tiny **ridges** into many noncellular, **hexagonal** areas, each with a hairlike **cilium** in its center. Embedded below the surface are spindle-shaped structures called **trichocysts** (Gr. *trichos,* thread; *kystos,* sac) which may discharge **trichocyst threads** when stimulated.

Cilia in the **oral groove** sweep food through the **mouth** into the **gullet (cytopharynx)** which forms **food vacuoles** in which digestion occurs by the action of **digestive enzymes.** The rhythmic vibration of cilia assists in locomotion. A **contractile vacuole** at each end of the animal collects wastes and, by contraction at intervals, discharges them. Indigestible materials are ejected through an **anus** just posterior to the oral groove.

Reproduction occurs asexually by **transverse binary fission.** At certain times two paramecia may attach themselves temporarily at their oral regions and build between them a **conjugating tube** through which they exchange nuclear materials by the process of **conjugation.** After separating, the two individuals may continue to divide by fission.

Study a prepared, stained slide of *Paramecium.* With a clean pipette place a drop of living *Paramecium* culture on a clean slide and add a clean cover slip.

DRAW a paramecium (enlarged), showing all parts labeled correctly.

Feeding habits may be observed by placing (with a clean pipette) a drop of living culture of *Paramecium multinucleatum* on a clean slide and adding a small drop of yeast mixture* which contains an indicator, Congo red. DO NOT ADD TOO MUCH YEAST MIXTURE. Apply a clean cover slip carefully. Observe at once in order to detect the first stages in the formation of **food vacuoles.** Above a hydrogen-ion concentration of 5.0 (pH 5.0) Congo red has an orange-red color; below pH 5.0 it has a deep blue color. What does this color change signify as you observe the paramecia?

The **conjugation** of *Paramecium bursaria* may be demonstrated as follows. The two mating types of this species of paramecium

*See Appendix 3.

will be known as **mating type A** (labeled PBA) and **mating type B** (labeled PBB). With a **clean pipette** place a drop of mating type A in one of the end depressions and also in the center depression of a (3-depression), concave slide. With a **different clean pipette** place a drop of mating type B in the depression in the opposite end of the slide and also in the center depression (where you placed mating type A previously). The paramecia in the 2 end depressions serve as controls. Why is this necessary? With proper magnification observe and explain the results in the cultures in each of the 3 depressions. BE CAREFUL THAT THE PIPETTES USED DO NOT COME IN CONTACT WITH THE DROPS IN THE DEPRESSIONS. Explain why this is important.

DRAW two paramecia in the process of conjugation, labeling correctly.

The discharge of threadlike **trichocyst fibers** may be observed in living paramecia if a small amount of a dilute solution of methyl green (dye)* is drawn under the cover slip of the preparation.

Plasmodium (class Sporozoa)

Protozoans of this genus belong to the class **Sporozoa** because they reproduce by **spores.** In the adult stage there are **no organelles of locomotion, no contractile vacuoles,** and **no digestive organelles.** Predigested foods are absorbed through the body surface.

Different species of *Plasmodium* infect man to produce various types of malaria, the protozoans being transmitted by a female mosquito of the genus *Anopheles.* Many stages constitute the life cycle in the body of man and in the mosquito. These stages are described and illustrated in the text. If desirable, the various stages of the complex life cycle may be considered in the laboratory and their methods of reproduction in the bodies of man and the mosquito may be studied.

DRAW a life cycle of *Plasmodium* with the various stages labeled and arranged in proper sequence.

Make a TABLE which summarizes the (1) methods of locomotion, (2) methods of securing food, (3) methods of excretion, and (4) methods of reproduction for each of the protozoans studied.

*See Appendix 3.

Monocystis (protozoan parasite of earthworms) (class Sporozoa)

This common gregarine (Gr. *grex,* flock) parasite is almost always found living in the large, lobed, seminal vesicles of the earthworm. Certain stages of the life cycle may be obtained by submerging a living worm in an anesthetic (7% alcohol or 5% chloretone) and carefully cutting the anterior part of the worm along the middorsal line. Locate the 3 pairs of large, lobed seminal vesicles which are found approximately in segments IX to XII. With a forceps pinch off a piece of the seminal vesicle and tease gently in 0.75% sodium chloride solution. Mount on a slide and examine microscopically.

Among other stages of the life cycle which may be observed identify the large, highly active **trophozoite** stage ($70\mu \times 200\mu$) (1μ is $\frac{1}{25{,}000}$ of an inch) which may resemble the shape of a spindle, top, or hour-glass. Identify the thick-walled **cysts** (160μ diameter) containing 2 mature **trophozoites** (now called **gametocysts**) which fuse. The trophozoites parasitize the earthworm reproductive system. The various stages of the complete life cycle are described in your text or other references.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and representative to prove or disprove them? Why do you say so? Explain any instances where you may have made errors in observations and interpretations, including any reasons why you may have done so.

In order to compare representative protozoans, prepare a table (on an accompanying page), including various traits. What traits do all protozoans have in common? In what ways do the members of the various classes differ from each other? Be accurate and specific in your answers.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Do these conclusions prove or disprove your hypotheses and problems? Why do you say so? Draw additional logical conclusions which may not be directly associated with the specific problems as stated. Do not draw conclusions which are not justified by the information collected.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Recheck particularly those places where you may have made errors in observation or interpretation. Repeat any observations which you think may have been erroneous.

Sponges, coelenterates, and ctenophorans

1. Problems

Are there certain advances in structures and functions over the protozoans which are shown by sponges, coelenterates, and ctenophorans? Are certain representatives of these phyla sessile (attached), and is this advantageous or detrimental when compared with highly motile organisms? Do sponges and coelenterates have certain traits in common even though they are in different phyla? In what general ways are representatives of these three phyla similar and in what ways do they differ? In what ways are animals with two or three cellular layers to be considered as being higher types than protozoans, even of the colonial protozoans? Do certain types possess a gastrovascular cavity in which digestion and circulation take place? Are sensitive tentacles an advantage to animals? How can nematocysts (stinging cells) be useful in animals? Do certain coelenterates possess a life cycle which illustrates an alternation of generations between an asexual stage and a sexual stage?

2. Preliminary observations and pertinent data and information

RECORD any accurate information concerning sponges, coelenterates, and ctenophorans which pertains to the problems, including only that which you know to be true.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable preliminary information which pertains to the problems formulate hypotheses from which you may work toward the solution of them. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study preserved specimens, prepared slides, projected slides, museum preparations, and life cycles as suggested by the instructor.

SPONGES (PHYLUM PORIFERA)

Scypha (Grantia) (class Calcarea)

This vase-shaped, sessile, radially symmetrical, marine sponge is about an inch long and has a skeleton of **calcareous (limy) spicules** of four types: (1) straight, **short monaxon,** (2) straight, **long monaxon,** (3) **triradiate** (3 rays in one plane), and (4) **polyaxon** (several rays). The body surface contains numerous **incurrent pores (ostia)** opening into **incurrent canals.** The latter end blindly near the central cavity, the **spongocoel (gastrocoel).** Openings in the spongocoel, called **apopyles,** open into **excurrent (radial) canals** which end blindly near the outer surface. The incurrent and excurrent canals are connected by small openings called **prosopyles.**

The incurrent canals are lined with **dermal epithelium** and the spongocoel and excurrent canals are lined with **gastral epithelium.** Excurrent canals contain flagellated collar cells, the **choanocytes,** to propel water and food through the incurrent canals, apopyles, excurrent canals, and then out through the larger **osculum** at the free end of the animal.

The body wall is composed of an outer **dermal epithelium,** an inner **gastral epithelium,** with a noncellular, jellylike **mesenchyme** between them. The mesenchyme contains wandering ameboid cells, the **amebocytes,** for ingesting foods, producing skeletal materials, and forming reproductive cells.

Foods are ingested by **pseudopods** on the collar cells and digested within their **food vacuoles** by means of **digestive enzymes.**

Scypha reproduces asexually by **budding,** and the young often remain to form a clusterlike colony. The ameboid cells produce both **sperms** and **eggs,** the latter being fertilized to form a **zygote,** which develops into a flagellated larval stage called the **amphiblastula.** The latter eventually attaches to form an adult *Scypha.*

Make such DRAWINGS of *Scypha* as desirable. Label correctly.

Venus's flower basket (Euplectella) (class Hexactinellida)

The skeleton is composed of siliceous, **6-rayed spicules** interwoven into a cylindrical network which resembles spun glass. The spicules surround the numerous pores and canals. Enlarged chambers on the canals are lined with **collar cells.**

DRAW a section of Venus's flower basket showing the skeleton, labeled correctly.

Commercial (bath) sponges (class Demospongiae)

The skeleton is composed of a network of branched **spongin fibers** composed of a proteinlike material. The **canals** are complex, much branched, and with numerous enlarged **chambers.** The latter are lined with **collar cells.**

DRAW a commercial sponge, including the spongin fibers, labeled correctly.

COELENTERATES (PHYLUM COELENTERATA) (CNIDARIA)

Hydra (class Hydrozoa)*

This fresh-water, cylindrical, radially symmetrical animal is called a polyp and may be temporarily attached by a **basal disk.** When distended the animal may be about ¼ inch long. A **mouth** is surrounded by 6 to 10 slender, extendable **tentacles.** The mouth opens into a **gastrovascular cavity (enteron).** Stinging cells, called **nematocysts,** are saclike, fluid-filled structures which contain a **coiled thread** and a triggerlike **cnidocil.** When the latter is stimulated the thread is uncoiled.

The body wall consists of an outer **epidermis (ectoderm),** an inner **gastrodermis (endoderm),** and a thin, jellylike **mesoglea** between them. The **epidermis cells** are typically cube-shaped and include such types as (1) **epitheliomuscular** with contractile fibers; (2) **cnidoblasts,** which contain the coiled nematocysts; (3) **interstitial,** which give rise to buds, nematocysts, reproductive gonads, etc.; (4) **gland** for secreting mucus; (5) **nerve** and **sensory,** which form part of the so-called **nerve net** (plexus of nerve cells).

The **gastrodermis cells** line the gastrovascular cavity, are typically column-shaped, and include (1) **digestive-muscular,** which ingest foods by means of **pseudopods,** digest foods in **food vacuoles** by means of enzymes, possess **flagella** and **contractile fibers;** (2) **gland** for secreting mucus and albumin; (3) **interstitial,** which give rise to other cells; (4) **nerve** and **sensory.**

Hydra reproduces asexually by means of **buds** which are formed as outpockets of the entire body wall. Sexual reproduction is accomplished by several **testes** (male gonads) which are rounded outgrowths near the mouth region and produce numerous **sperms** (one flagellum) which swim in the water. A larger **ovary** (female gonad) is formed nearer the basal end and produces an **egg** which is fertilized to form a **zygote.** The latter develops into a hollow **blastula** which is followed by a solid **gastrula** by filling the cleavage cavity with endodermal cells. A shell-like resistant **cyst** forms around the embryo which now leaves the parent. Such an embryo may pass the winter and continue its development when conditions are favorable. After a time the shell breaks and the young hydra with tentacles emerges and grows to become an adult.

Make such DRAWINGS of *Hydra* as

*Two common types of hydra are the brown hydra, *Pelmatohydra oligactis* (Gr. *pelmatos,* bottom or sole of foot; *hydor,* water) (Gr. *oligos,* few) and the green hydra, *Chlorohydra viridissima* (Gr. *chloros,* green) (L. *virescere,* to become green) because of algalike *Zoochlorella* living symbiotically in its cells.

will show the above structures, labeled correctly.

Behavior of living hydra

The hydra responds to various stimuli and its physiological state influences to a great extent the nature of its responses. When hydra is well fed it is slow in responding to most stimuli, but if hungry, it may react to the same stimuli vigorously. The reactions depend partly on the intensity and kind of stimulus. The movements are produced by an opposite set of contractile fibers in the body and tentacles and are due to the coordinated transmission of impulses through its nerve net.

In order to observe the feeding habits of hydra, place (with a clean medicine dropper) a drop of living hydra culture in a clean concave slide and add some hatched, marine, brine shrimps.* Let the hydra feed for not more than 30 minutes. Pour off the water after feeding and rinse the hydra, which will usually remain attached. If excess brine shrimps are not removed after 30 minutes, they die in fresh water, polluting it and killing the hydra.

If the stock hydra culture is to be kept for some time, the water should be changed (hydra rinsed) daily. Once every 2 weeks (or more often if necessary) the hydras should be put in a clean glass dish because the old one becomes slimy and polluted. Water should be changed daily, even though hydra may not be fed. Things which kill hydra include dirty water, salty water, dead food, copper in tap water, etc.

Instead of the above observation of feeding habits of hydra, place a drop of living hydra culture in a clean, concave glass slide (or watch glass). With a clean pipette place a few living crustaceans, such as *Daphnia,* in the drop of culture and observe the capture and ingestion procedures. Describe what happens as accurately as possible.

In order to observe additional behaviors of hydra, prepare a slide as above and subject the animal to (1) slight jarring; (2) temperature from a light bulb or infrared lamp; (3) coldness by placing the slide on an ice cube for a time and observing immediately; (4) chemicals such as salt, acetic acid, etc.; (5) contact with a clean needle (on a single tentacle and on the body, both near the mouth and near the base); (6) a strong magnet; (7) additional stimuli as suggested.

Obelia and Gonionemus (class Hydrozoa)

Obelia is a marine, colonial animal which illustrates the phenomenon of **alternation of generations** because its budding, asexual generation is a conspicuous, polyp-type, **hyroid stage,** and its sexual generation is a small inconspicuous, jellyfish-type, **medusoid stage.**

Gonionemus is another marine hydrozoan which illustrates **alternation of generations** because its asexual generation is a tiny, inconspicuous polyp, the **hydroid stage,** and its sexual generation is a conspicuous, jellyfish-like **medusoid stage.** The two most conspicuous generations of these two different animals are frequently studied together to illustrate alternation of generations.

The attached, hydroid stage of *Obelia* has many branches which contain numerous (1) **nutritive hydranths** with a **mouth** and numerous **tentacles** with **nematocysts,** and (2) club-shaped **reproductive gonangia.** The latter produce asexual **buds** which develop into umbrella-shaped **medusae** with **tentacles** around the margin. The sexual medusae give rise to **sperms** (in **testes**) in one individual and **eggs** (in **ovaries**) in another individual. The fertilized egg eventually develops into the hydroid stage again. The entire animal has an outer, horny **perisarc.** Inside the latter is a tubular **coenosarc** consisting of **ectoderm, mesoglea,** and **endoderm.** The internal **gastrovascular cavity** is continuous throughout the colony.

The medusoid stage of *Gonionemus* is umbrella-shaped and is about ½ inch in diameter. **Nematocyst-bearing tentacles**

*Marine, brine shrimps may be secured by placing a quart of clean pond water (not tap water) in a shallow, clean, glass dish and adding 1 heaping tablespoonful of table salt. Add 2 "pinches" of brine shrimp eggs to the surface and leave undisturbed for 2 days at a rather constant temperature of 75° F. Then filter through a cloth net which will catch the hatched shrimps. Wash the shrimps in the net with tap water. Wait a few minutes and the hatched shrimps will swim toward the light and away from the unhatched eggs.

Name ______________________

Section ______________________

Date ______________________

COMPARISON AND CONTRAST OF SCYPHA, HYDRA, AND PLEUROBRACHIA

	Scypha (Grantia) ***(Porifera)***	**Hydra** ***(Coelenterata)***	**Pleurobrachia** ***(Ctenophora)***
Symmetry			
Body wall construction			
Central cavity			
Skeletal materials			
Locomotion			
Reproduction			
Miscellaneous and drawing			

fringe the margin. The concave, oral side is called the **subumbrella** and has a shelflike, membranous **velum** which covers the concave side. Water forced through a hole in the velum propels the animal in a jetlike manner. Hanging down from the subumbrellar surface is a tubular **manubrium** at the tip of which is a **mouth.** The latter opens into a **gastrovascular cavity** with 4 **radial canals** which lead to a **ring canal. Testes** are attached to the radial canals of some individuals, and **ovaries** are attached to other individuals.

Make such DRAWINGS of *Obelia* as will show the above, labeled correctly.

Make such DRAWINGS of *Gonionemus* as will show the above, labeled correctly.

Sea anemones and corals (class Anthozoa)

The sea anemone *(Metridium)* is a marine, cylindrical coelenterate with circles of hollow, **nematocyst-bearing tentacles** around the **mouth** and a **pedal disk** for attachment. The mouth opens into a **gullet** which leads into the **gastrovascular cavity (enteron).** The latter is divided into radially arranged **chambers** by pairs of membranous **mesenteries (septa).** Near the base are long, threadlike **acontia** which bear **nematocysts.** Asexual reproduction may occur by **budding. Sex organs (gonads)** are present on the margins of the mesenteries, the sexes being separate **(diecious).**

The coral is a marine **polyp** with short **tentacles,** and it lives in a stony, **cuplike structure.** The polyp is constructed somewhat like the sea anemone but it secretes a **calcareous skeleton (coral)** around itself and between its **mesenteries,** thus dividing the cup radially into ridges. The living polyps may withdraw into these cups. A number of individuals usually live together to form a colony, but some species are solitary. They may display many branches or may be round masses. Various colors are found in different species.

Make DRAWINGS of sea anemones and corals showing the above, labeled correctly.

CTENOPHORANS (PHYLUM CTENOPHORA)

Pleurobrachia

This marine, transparent, oval-shaped, biradially symmetrical animal is less than 1 inch in diameter. It has 8 locomotor **comb plates,** each of which is made of rows of long, fused **cilia.** Two long, solid **tentacles,** with **lateral branches,** are **without nematocysts** and may be retracted into saclike **protective sheaths.**

Ctenophorans consist of an outer, ciliated **epidermis (ectoderm);** a simple middle **mesoderm** with scattered ameboid cells and muscle cells; and an inner **endoderm** which lines the **gastrovascular cavity.** *Pleurobrachia* locomotes by beating the cilia on the comb plates. Both male and female gonads are located under the comb plates of the same animal *(monecious).*

DRAW *Pleurobrachia* showing the above, labeled correctly.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Did you study a sufficient number of representative animals to give enough reliable information to prove or disprove the problems? Why do you say so? Explain instances where you may have made errors in observations and interpretations and consequently may have secured inaccurate information. Include reasons why you may have made errors and ways for correcting them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified with the evidence available? Do the conclusions prove or disprove the hypotheses and problems? List any additional conclusions you may draw from your studies which may not be directly associated with the problems as stated.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Recheck particularly those instances where you may have made errors in observation and interpretation. Repeat wherever an error may have been made.

Flatworms (phylum Platyhelminthes)

1. Problems

In what ways do flatworms show certain advancements over animals previously studied? When a digestive system is present, is it of the gastrovascular type and without an anus, or is it complete with an anus? Do flatworms possess bilateral symmetry? Is the body of flatworms developed from three embryonic germ layers (ectoderm, mesoderm, endoderm)? Are wastes propelled through tubular excretory canals by means of flame cells (vibrating cilia)? Is the nervous system typically composed of cerebral ganglia with paired longitudinal nerve cords? Are certain flatworms without digestive systems and sensory equipments? In general do flatworms possess complex reproductive systems? Are the life cycles of liver flukes complex and composed of numerous larval stages in two or more hosts? Do planarians display an axial gradient with progressively decreasing rates of metabolic activities from the anterior toward the posterior end? Do certain flatworms possess protective structures which are advantageous to them? Do the life cycles of liver flukes show the phenomenon of pedogenesis (reproduction by immature, larval stages)? Do parasitic flatworms cause diseased conditions in a variety of animals?

2. Preliminary observations and pertinent data and information

RECORD all the accurate information which you can concerning planarians, flukes, and tapeworms which pertains to the problems, including only that which you know to be true.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable preliminary information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study living specimens, preserved materials, prepared slides, projected slides, museum preparations, and life cycles, as suggested by the instructor.

Dugesia (Planaria) (class Turbellaria)

This fresh-water turbellarian has a flat, mottled, ciliated body less than 1 inch long. The arrow-shaped **head** has two lateral **auricles** and two light-sensitive, dorsal **eyespots.** Two **ciliated pits** on the side of the head may be concerned with taste and smell. **Rodlike rhabdites** embedded in the **epidermis** serve as sensory structures.

Planarians may locomote by gliding over a slimy band of mucus secreted by the epidermis and by the beating of the **cilia.** Body movements may also occur through the action of internal muscles.

A ventral **mouth** located at the end of a tubular, sucking **pharynx (proboscis)** connects with a multibranched **intestine (enteron)** consisting of three main branches. The intestine serves as a **gastrovascular cavity** and does not have an anus. Wastes are eliminated by two longitudinal, branched, **excretory canals.** The canals have numerous terminal, **flame cells,** which contain a tuft of vibrating **cilia** which flicker like a flame.

The nervous system consists of two **cerebral ganglia** ("brain") connected to two lateral, **longitudinal nerve cords.** Planarians may reproduce asexually by dividing (**fission**) transversely posterior to the pharyngeal region and each part reorganizing into a complete animal. Each animal has numerous spherical **testes** and a pair of **ovaries** so that it is **monoecious.** Many accessory reproductive organs are quite well developed.

Planarians have remarkable abilities to regenerate lost parts. When cut in two the anterior end will regenerate a new tail and the posterior part a new head. They illustrate the theory of the **axial gradient** because there are progressively decreasing rates of metabolism as we progress from the head toward the tail region. In any segment a head may develop where the metabolic activity is greatest, and a tail where it is least. Metabolic rates may be measured by oxygen consumption and carbon dioxide production.

DRAW a planarian (external view), labeled correctly.

DRAW a planarian showing internal structures, labeled correctly.

Liver fluke (class Trematoda)

The Oriental liver fluke *(Chlonorchis sinensis)* is parasitic in the bile ducts of man and other mammals, especially in eastern Asia. In general its characteristics and life cycle are somewhat like those of the sheep liver fluke *(Fasciola hepatica)* which is parasitic in the liver of sheep, cows, and pigs where it may cause great damage. Many flukes have complex life cycles with a number of larval stages in two or more hosts.

The adult of *Clonorchis* has a rough **cuticle** but lacks external cilia, and may be over 1 inch long. A **mouth** is located within the **anterior (oral) sucker,** and there is a **ventral sucker** posterior to the anterior sucker. A muscular **pharynx** is attached to two long **intestines** without an anus. Two **excretory tubes,** whose branches terminate in **flame cells,** propel the wastes through a posterior **excretory pore.** The nervous system consists of two **cerebral ganglia** connected to two **longitudinal nerve cords.**

The reproductive system, in part, consists of multibranched **testes** for producing **sperms;** a **sperm duct** (seminal vesicle); a lobed **ovary** attached to a **shell gland** which receives yolk (food) from two lateral **yolk glands;** an oval **seminal receptacle** connected with the **oviduct;** a coiled **uterus** which extends to the **genital pore** just anterior to the ventral sucker.

The life cycle of *Clonorchis* is quite complex and the details should be studied from the text or other references. Briefly, the stages are as follows: (1) the **adult stage** is normally spent in the bile ducts of man and the **eggs** pass out with the feces and may find their way into water; (2) each egg contains a ciliated **miracidium;** (3) if eaten by certain species of fresh-water snails, the miracidium bores its way into the tissues of the snail. (4) each miracidium is transformed into a baglike **sporocyst;** (5) the reproductive cells within the sporocyst develop into elongated **rediae** which are liberated when the sporocyst ruptures; (6) the reproductive cells within the rediae develop into tadpolelike **cercariae** which leave the snail and develop further only if they enter the body of certain fresh-water fishes; (7) in the fish the cercariae lose their tails and encyst to form **metacercariae;** (8) if improperly cooked fish with metacercariae is eaten by man, the protective cyst is dissolved and the metacercariae move up the human bile ducts to become adults where they may live for years and do greater or lesser damage.

DRAW the life cycle of *Clonorchis* with all parts of each stage labeled correctly.

Tapeworm (Taenia) (class Cestoda)

The adult pork tapeworm *(Taenia solium)* is a flat, ribbon-shaped parasite which lives in the human intestine and may be over 10 feet long. Larval stages may be associated with muscles of infested pigs. The adult has an enlarged **scolex** with **suckers** and **hooks** for attachment. The body is covered with a protective, non-ciliated **cuticle.** The body is composed of a linear series of **proglottids** (individuals) which may number several hundreds. New proglottids are formed in the neck region by a process of transverse **budding,** so that narrow, immature proglottids are nearest the scolex and broader, mature ones toward the posterior end.

There is no digestive system, predigested foods being absorbed from the surroundings. Two lateral **excretory canals** with **flame cells** excrete wastes. Two **lateral nerve cords** also run throughout the proglottids and terminate in a **nerve ring** in the scolex. Each proglottid is monoecious, having a complete set of male and female sex organs.

DRAW a tapeworm showing scolex and proglottids, labeled correctly.

The male reproductive system consists of many spherical **testes** which are connected to a **sperm duct (vas deferens)** which leads to the **genital pore.** The female reproductive system consists of a multi-branched **ovary,** an **oviduct, yolk gland** to supply food, **shell gland,** a saclike **uterus,** and a tubular **vagina** which leads to the **genital pore.** As the uterus matures with its developing eggs it may become branched and nearly fill the proglottid.

DRAW a mature proglottid with parts labeled correctly.

When a pig swallows a proglottid or an egg, the shell of the latter is dissolved. The **6-hooked embryo** which develops finally burrows through the intestine wall and enters the blood vessels. It finally encysts in muscles to form a saclike **bladder worm,** called a **cysticercus.** After several weeks the latter forms an **invaginated (turned in) scolex** with suckers and hooks. Finally the bladder disappears and there is formed an **evaginated (turned inside out) scolex** which attaches to the intestine and forms new proglottids.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were the studies sufficiently extensive to provide enough reliable information to prove or disprove the problems? Why do you say so? Explain instances where you may have made errors in observation or interpretation and consequently may have secured inaccurate information. Include reasons why you may have made errors and ways for correcting them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they justified and valid from the evidence available? Do your conclusions prove or disprove the hypotheses and problems? List any additional conclusions you may draw from your studies which may not be directly associated with the problems stated. Be sure that these additional conclusions are accurate and valid as far as your information is concerned.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure pertinent, reliable information. Recheck particularly those instances where you may have made errors in observations and interpretations. Repeat wherever an error may have been made.

Roundworms or "cavity worms" (phylum Aschelminthes) (Nemathelminthes)

1. Problems

Do roundworms possess an alimentary canal complete with mouth and anus? Does such a digestive system possess regions which are specialized in different ways for greater efficiency? Is this an advantage over a gastrovascular type which has no anus? Is bilateral symmetry characteristic of roundworms? Is the body of roundworms developed from three embryonic germ layers (ectoderm, mesoderm, endoderm)? Do roundworms ("cavity worms") possess a false, unlined body cavity called a pseudocoele? In general do roundworms show sexual dimorphism, whereby the two sexes may be distinguished by means other than the sex organs? Do many types of roundworms (nematodes) parasitize plants and other animals, whereas many other forms are free-living in soils, waters, etc.? In general are the host requirements for the life cycles of roundworms as complex as those of flatworms?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you have concerning roundworms (*Ascaris,* hookworms, trichina [pork] worm, rotifers) which pertains to the problems, including only that which you know to be true.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study living specimens, preserved materials, prepared slides, projected slides, museum preparations, and life cycles, as suggested by the instructor.

Parascaris (Ascaris) (class Nematoda)

The roundworm, *Parascaris equorum* (originally *Ascaris megalocephala*), may be parasitic in the horse intestine. The body is long, slender, smooth, unsegmented, and pointed at both ends. The males are about 6 inches and the females about 9 inches long. The former have a **curved posterior end** which bears bristle-like **penial spicules** near the **genital pore** at the posterior end. Because the two sexes can be distinguished by structures other than the sex organs, they illustrate **sexual dimorphism.** There is a thick, protective **cuticle** without cilia. One dorsal and two ventral **lips** surround the **mouth** and bear sensitive **papillae.**

The false body cavity, the **pseudocoel,** is not lined with mesoderm. The body wall contains **longitudinal muscles** which are divided into bandlike parts by **lateral lines.**

The digestive system consists of a **mouth,** a short, muscular, sucking **pharynx,** a long **intestine** for absorption, a short **rectum,** and an **anus** at the posterior end. In each of two lateral lines is an **excretory tube** without flame cells. The two tubes unite and empty wastes through a ventral **excretory pore** just posterior to the mouth. From a circumpharyngeal **nerve ring** arise one dorsal and one ventral **nerve cord.**

The sexes are separate (dioecious). In the male one coiled, threadlike **testis** produces **sperms** which are conducted by a tubular **vas deferens** to an enlarged **seminal vesicle** where they are stored. A muscular **ejaculatory duct** empties into a cloaca. Two bristlelike, chitinous **penial spicules (setae)** attach the male during copulation.

In the female two coiled, tubular **ovaries** produce **eggs.** Two tubular **oviducts** carry eggs to two larger **uteri** which unite and empty into a short **vagina** which opens through a **genital pore** about one-third of the way back from the anterior end. Fertilization occurs in the uteri, and the eggs are protected by a thick, rough shell.

DRAW *Parascaris* (Ascaris) which has been dissected to show a dorsal view, with all parts labeled correctly.

The development of tissues and organs at this level of the animal kingdom may be observed by studying a prepared stained slide of a cross section of an Ascaris worm.

The **body wall** consists of (1) a noncellular, external **cuticle** below which is a thin layer of (2) **epidermis** (ectoderm) which contains many nuclei and may not contain cell walls, hence is a syncytium (sin sit'ium) (Gr. *syn,* with; *kytos,* hollow), and beneath this is (3) a layer of longitudinal **muscles,** somewhat divided into four bands and composed of specialized epitheliomuscular cells.

If the cross section is cut at the proper level of the animal the **intestine wall** consists of (1) a thin, external layer of **cuticle,** (2) a single layer of column-shaped **endoderm cells,** and (3) an inner, thin layer of **cuticle.**

The internal cavity is a **pseudocoel** (false coelom) because it does not originate embryologically by a splitting of the mesoderm as is true in animals having a true coelom.

A pair of longitudinal **excretory canals** may be observed in cross section as hollow tubules embedded opposite each other and in the **lateral lines** in the body wall. Longitudinal **nerve cords** (one dorsal and one ventral) are connected to the circumpharyngeal **nerve ring** in the anterior part of the body.

The **male reproductive system** consists of a single, tubular **testis** which is very much coiled and in cross section may appear more or less circular in shape. The testis leads into a larger, tubular **vas deferens (ductus deferens)** which in turn leads into a still larger **seminal vesicle** (for sperm storage). Depending on where the section is cut, there may also be a saclike **setal sac** into which the penial seta may be retracted.

The **female reproductive system** consists of a pair of small, tubular **ovaries** (wheel-shaped in cross section) leading into larger paired, coiled **oviducts** connected with expanded, paired **uteri,** which may contain **eggs.** The uteri unite posteriorly to form a tubular **vagina.** The ovaries in cross section may appear solid (containing eggs?) and more or less circular in shape. The oviducts and uteri will usually be relatively larger and may or may not contain materials internally.

Hookworm (class Nematoda)

The adult American hookworm, *Necator americanus,* is about 12 mm. long, the males being slightly shorter than the females. The hooklike body bears platelike **teeth** in the **mouth** for cutting holes in the human intestine. They suck blood and other fluids by means of a sucking **esophagus** and digest them in the **intestine.**

When larval stages (0.5 mm.) from the soil contact the skin, they burrow into the blood vessels causing an irritation. After a complex migration within the human body they finally reach the intestine.

DRAW a hookworm (adult) with all structures labeled correctly.

Trichina (pork) roundworm (class Nematoda)

This human parasite, *Trichinella spiralis,* averages about 3 mm. in length and lives in the human intestine, having been ingested with improperly cooked pork. The larvae (0.1 mm. long) enter the veins and lymph vessels from which they are carried to various parts of the body, especially the skeletal muscles. Here they coil, become surrounded by a limy **cyst** (0.5 mm. diameter), and may live for years. When these trichina cysts are ingested with infested pork the larvae are liberated in the human intestine.

DRAW a trichina cyst imbedded in muscles, labeled correctly.

Rotifers (class Rotifera)

The different species of rotifers vary from 0.5 to 1.5 mm. in length. They are aquatic, multicellular, usually cylindrical, with a broad anterior **head**, a large **trunk**, and tail-like **foot**. Rotifers are characterized by one or two **rows of moving cilia** (**"wheel organ"**) on the head. The foot contains **pedal glands** to secrete a sticky substance for attachment.

Foods are drawn into the **mouth** by the **"wheel organ"** and are passed into a **pharynx** which has a pair of **horny jaws** (**mastax**) which move actively from side to side. Foods are digested in the **stomach.** An **intestine** leads to a **cloaca** ("sewer") which empties through an **anus.**

The sexes are separate (dioecious). Males are less common and usually are smaller than females (sexual dimorphism). In some species three kinds of eggs are formed: thin-shelled **summer eggs** of two sizes which develop by **parthenogenesis** (without fertilization), the larger eggs developing into females and the smaller into males; thick-shelled, resistant **winter eggs** which develop into females after fertilization.

Study stained slides and living cultures of rotifers.

DRAW a rotifer, showing as many of the structures as possible, labeled correctly.

Behavior and feeding habits of living rotifers

Rotifers may be cultured by preparing a liter (approximately 1 quart) of water which has been sterilized to kill contaminating organisms. Tap water may be used unless it contains such noxious chemicals as chlorine, etc. It may be desirable to adjust the pH to about 7.0, using a phosphate. After 1 gram of nonfat dried milk is dissolved in the water, inoculate with rotifers and incubate at about 20° C. The population of rotifers should be adequate within two weeks and will survive for some months. Rotifers may be removed for subculturing within one week.

Study slides of living rotifers, observing their feeding habits, the action of the circular band of cilia ("wheel organ") at the anterior end, the sidewise movement of the pair of internal jaws (mastax), the behavior when colliding with foreign objects, etc.

Add any additional observations to your original DRAWING.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and detailed to supply valid proof? Why do you say so? Did you make errors in observations and interpretations? If so suggest methods whereby they may be corrected.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified from the available evidence? Do your conclusions prove or disprove the hypotheses and problems? State additional conclusions which may not be directly associated with the problems. Be sure that these additional conclusions are valid and accurate considering your information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Recheck carefully where you may have made errors, repeating until you are certain that your observations and interpretations are correct.

Segmented worms (phylum Annelida)

1. Problems

How could a linear series of segments be advantageous in the construction of an animal body? Do annelids possess a true body cavity (coelom) arising from and lined by the mesoderm? Do annelids have a body wall composed of circular and longitudinal muscles, epithelial tissues, and an external cuticle? Is the wall of the intestine of an earthworm composed of several well-developed tissues? Do certain annelids possess bristlelike setae for appendages? Do members of this phylum possess a separate, so-called "closed" type of circulatory system in which blood circulates in a continuous series of vessels? Do earthworms possess a series of pulsating loops ("hearts") for propelling blood? Are wastes eliminated by specialized, paired, tubular structures called nephridia? Does the nervous system consist of paired, dorsal, cerebral ganglia (brain) with two ventral nerve cords? Do ventral nerve cords have enlargements, known as ganglia, whereby nerve impulses may be received and redirected? How is the absorbing surface of the earthworm intestine increased without increasing its length? Are earthworms monoecious (hermaphroditic)? What advantages might hermaphroditism be to an animal?

2. Preliminary observations and pertinent data and information

RECORD all the information which you have concerning annelids (earthworms and leeches) which pertains to the problems, including only that which is accurate.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study living specimens, preserved materials, prepared slides, projected slides, museum preparations, and life cycles, as suggested. Many of the important structures and functions may be learned by making the following observations.

Earthworm (class Oligochaeta)

The earthworm, *Lumbricus terrestris*, has an elongated, bilaterally symmetrical body composed of a linear series of ringlike **body segments** (**metameres** or **somites**), showing a simple type of **metamerism.**

External structures. Locate each of the following regions: (1) **anterior end,** in which the segments are largest and the body is round, (2) **posterior end,** in which the segments are smaller and the body is usually somewhat flattened, (3) **dorsal surface,** which is usually darker than the ventral surface and frequently has a rather heavy, dark line which extends down the middle region because of the presence of a large blood vessel beneath the surface, and (4) **ventral surface,** which is usually lighter in color and possesses pairs of **setae** (bristlelike structures) which may be detected by running the finger over the surface. Observe the **bilateral symmetry** of the animal. Does it have a right and left side?

At the tip of the anterior end note the incomplete ringlike **prostomium** which is arched dorsally over the **mouth.** Observe the conspicuous, bandlike **clitellum** (L. *clitellum,* saddle) which incompletely encircles the body about one-third the distance from the anterior end to the posterior end. Count the exact number of segments from the anterior end to the clitellum. Compare your count with others at your table. Observe the pairs of bristlelike setae on the ventral surface as well as on the sides of each segment. These setae have muscles attached to them internally so that they may be pointed in various directions, thus aiding the earthworm in crawling. If a piece of the body be allowed to dry the setae can be seen as distinct bristles. Beneath the dorsal surface can usually be seen a dark line, the dorsal blood vessel. Notice the **mouth** at the anterior end under the **prostomium** and the **anus** at the posterior end.

Internal anatomy (posterior end). The internal organs of the posterior end of the body may be studied by dissecting as follows. Place the animal, dorsal side up, in the dissecting pan and place a pin in the **anterior** end and also one in the **posterior** end. Stretch the body slightly. The **alimentary canal** lies close up against the dorsal surface, like one tube inside another. Be careful not to destroy it while dissecting. Make a slight incision some little distance from the posterior end and then cut forward for an inch or two, keeping the point of the scissors high so as not to cut the internal organs. By raising the tissues just as the cut is made the body wall is raised above the canal. Pin down the sides of the animal, stretching the segments as they are pinned.

Observe the tubular **alimentary canal** located at the median line. It may be constricted at intervals to correspond to the external segments of the body. Note the infolding of the dorsal wall of the intestine, known as the **typhlosole** (Gr. *typhlos,* blind; *solen,* channel), to increase the digestive surface. The intestine and dorsal blood vessel are surrounded by a layer of **chlorogogen cells** (Gr. *chloros,* light green) whose function may be to aid in food digestion and waste elimination. Observe the **dorsal blood vessel** which lies dorsal to the typhlosole.

Locate the **septa** (partitions) which divide the body cavity into compartments. With a hand lens locate the coiled, tubular **nephridia** (ne-frid′ i a) (Gr. *nephros,* **kidney**), one on either side of the **body in** each compartment. Each **nephridium** consists of (1) an enlarged, ciliated, funnel-shaped **nephrostome** (nef′ ro stom) (Gr. *nephros,* kidney; *stoma,* opening) whose **cilia** create currents to draw in wastes from the **coelomic fluid,** and (2) a thin, ciliated, coiled **nephridial tube** whose **glands** remove wastes and pass them to the exterior through the **nephridiopore.** Each nephridium occupies two compartments, the nephrostome in one compartment and the nephridial tube with its nephridiopore in the one immediately posterior.

Remove a section of the intestine and observe the **typhlosole.** Observe the whitish, **ventral nerve cord** located ventrally just below the point where the intestine has been removed. Note that the **ventral nerve cord** is enlarged in each segment to form a **ganglion** (Gr. *ganglion,* a "tumor") which gives off 3 pairs of **nerves.**

In addition to the **dorsal blood vessel** (not easily seen in gross dissection) there are a **ventral blood vessel** located beneath the alimentary canal but above the nerve cord, a **subneural blood vessel** located below the nerve cord, a pair of **lateral neural blood vessels,** one on each side of the nerve cord, and numerous, minute **capillaries** which connect the various blood vessels.

Internal anatomy (anterior end). The internal organs of the anterior end of the body may be studied by dissecting as follows.

ORDER OF DISSECTION. Pin the specimen, dorsal side up, with a pin through the muscular pharynx (located internally in segments IV and V), leaning the pin forward so as not to interfere with the view. Stretch the specimen slightly and place a pin back of the **clitellum,** leaning the pin backward.

Make a longitudinal, dorsal incision along the median line, beginning at the clitellum and cutting anteriorly. Pin the segments with just enough pins to hold them in position, leaning the pins outwardly so as not to interfere with the view with the hand lens. Remove the pin placed in the pharynx and continue the dissection to the anterior end. Be very careful when dissecting the last 5 segments at the anterior end, or the nervous system, pharynx, etc. may be destroyed.

DIGESTIVE SYSTEM. Starting at the anterior end identify each of the following in the proper sequence: (1) the **mouth cavity** (buccal pouch) in body segments I to III, (2) the muscular **pharynx,** occupying segments IV and V, which is so closely attached to the body wall by tissues that it may be flattened by pinning, (3) the thin-walled, tubular **esophagus** which extends from segments VI to XIV, (4) the 3 **pairs of calciferous glands** at the side of the esophagus, in segments X to XII, which produce lime to neutralize acid foods, (5) the thin-walled **crop,** for storage, is located in segments XV and XVI, (6) the thick-walled **gizzard,** for grinding, which is located in segments XVII and XVIII (open the gizzard, noting the contents and structure of the wall), (7) the tubular **intestine** with its typhlosole which extends from the gizzard to the anus at the posterior end of the animal.

CIRCULATORY SYSTEM. (1) **Five aortic arches ("heart" loops)** encircle the esophagus in segments VII to XI. They may be prominent in fresh specimens but in preserved ones they frequently appear as broken lines, only the original contents which have coagulated and broken into fragments being visible, whereas the walls are usually not seen. Sometimes some of the loops are concealed by septa, seminal vesicles, etc. (2) The **dorsal blood vessel** dorsal to the alimentary canal may be obscured by other structures in certain regions; its distribution over the pharynx may be observed. (3) The **ventral blood vessel** can be seen by turning the alimentary canal to one side, especially after completing the work on the reproductive system. (4) The **subneural blood vessel** is located beneath the ventral nerve cord. (5) A **pair of lateral neural vessels** are located on either side of the ventral nerve cord. (6) Numerous, minute **capillaries** cannot be seen in gross dissections; they connect the other blood vessels, making a "closed" system. (7) The **blood** consists of a liquid **plasma** with an oxygen-carrying **pigment (hemoglobin)** dissolved in it.

REPRODUCTIVE SYSTEM. Both male and female sex organs occur in the same individual (**monecious or hermaphroditic**), although cross fertilization takes place.

The **male sex organs** include (1) **two pairs of hand-shaped testes** in segments X and XI, (2) **one pair of vasa deferentia (sperm ducts)** whose **ciliated funnels** collect the **sperm** and transport them through the tubular portion of the ducts (segments X to XV) to the exterior in segment XV, and (3) **three pairs of seminal vesicles** (segments IX to XII) which store sperm until they are transferred to the seminal receptacles of the opposite worm during copulation.

The **female sex organs** include (1) **one pair of ovaries** in segment XIII which are difficult to see except when full of **ova** (eggs), when they appear as pear-shaped structures near the median line, (2) **one pair of oviducts** which open by a **ciliated funnel** near each ovary in segment XIII, (3) an **egg sac** in segment XIV (each oviduct enlarges into an egg sac) which passes to the exterior in segment XIV, (4) **two pairs of seminal receptacles (spermathecae)** in segments IX and X which receive the sperm from the seminal vesicles of the opposite worm during copulation; the seminal receptacles are round and white and can best be seen when the alimentary canal has been removed; they are not easily seen before copulation when, naturally, they would be empty; **two pairs of openings for the seminal receptacles** are found on the exterior, ventral surface between segments IX and X and X and XI.

NERVOUS SYSTEM. The alimentary canal should now be removed, beginning at the crop and detaching toward the anterior end. Observe the ventral blood vessel, seminal receptacles, and such other structures not seen previously. (1) Before removing the pharynx observe the bilobed **cerebral ganglion** ("brain") dorsal to the pharynx in segment III (it may be obscured by other tissues). (2) **Ringlike circumpharyngeal** connectives connect the cerebral ganglion with a **pair of subpharyngeal ganglia** which lie just beneath the pharynx. (3) The **ventral nerve cord** extends posteriorly from the subpharyngeal ganglia and enlarges into a **ganglion** in each segment and gives off **three pairs of nerves** in each segment.

EXCRETORY SYSTEM. Paired, tubular **nephridia** are present in each segment except the first three and the last. They may be observed best in the posterior part of the animal because of the crowded condition of organs in the anterior end.

RESPIRATORY SYSTEM. **Oxygen** and **carbon dioxide** are exchanged through the moist **body surface. Capillaries** just beneath the external cuticle contain **blood plasma** with **hemoglobin,** the latter combining with oxygen.

DRAW to show the various systems in the anterior end. Beginning at the anterior end label each body segment with the proper Roman numeral (I, II, III, IV, etc.). Be certain that each organ is drawn in the correct body segment. Make the drawing sufficiently large so that details can be shown clearly and labeled correctly.

Tissues of the body wall and internal organs. Examine a stained slide of a cross section of an earthworm to study tissues. The body wall consists of the following 5 layers, beginning with the outside layer or the **cuticle.**

CUTICLE. This is a thin transparent membrane not composed of cells and perforated with fine pores. It is a product or secretion of the **hypodermis.**

HYPODERMIS (EPIDERMIS OR SKIN). The hyodermis is a layer of **columnar epithelium** composed of several kinds of elongated cells set vertically to the surface of the body. Some of these, known as **gland** cells, have the power of producing within their substance a glairy fluid (**mucus**) which exudes to the exterior through the pores in the cuticle. Others (**sensory cells**) give off from their inner ends nerve fibers which may be traced inward to the ganglia. The clitellum is produced by an enormous thickening of the hypodermis caused especially by the great development of the gland cells. (The clitellum may not be present in the section you study.)

CIRCULAR MUSCLES. A layer of parallel muscle fibers encircle the body; on the upper surface they are intermingled with connective tissue cells containing a granular brownish substance (pigment) which gives to the dorsal aspect its darker tint.

LONGITUDINAL MUSCLES. A layer of muscle fibers extend lengthwise of the body. They are arranged in complicated bundles which in cross section have a feathery appearance. In longitudinal section they have a simple fiber appearance and resemble the circular fibers as they appear in cross section. The circular muscles are arranged in somewhat similar bundles, as may be seen in the cross section.

COELOMIC OR PERITONEAL EPITHELIUM. This is a very thin layer of flattened cells next to the coelomic cavity.

DRAW a cross section of the earthworm (4 inches in diameter) from a careful study of a stained slide. Add all the details you can, especially the cellular structure of the 5 layers of the body wall. Label all structures accurately.

Study the same cross section slide, this time examining the cellular structure of the wall of the alimentary canal. The wall of the alimentary canal appears as a ring surrounded by the **coelom (body cavity).** The **typhlosole** may be seen as an infolding of the dorsal portion of the intestine and may be somewhat filled with **chlorogogen cells.** The intestinal wall is composed of 5 layers as follows (starting from the hollow cavity on the inside of the intestine): (1) **lining epithelium (endoderm),** a layer of closely packed, narrow, column-shaped cells with oval nuclei, (2) **vascular layer,** consisting of numerous, minute blood vessels, (3) **circular muscles,** a thin layer of elongated muscle fibers which encircle the intestine, (4) **longitudinal muscles,** a layer of muscle fibers which extend lengthwise along the intestine (remember that you are looking at these longitudinal muscles in cross section), and (5) **chlorogogen cells,** an external layer composed of large cells containing minute granules; the cells may fill the hollow typhlosole and even cover the dorsal blood vessel.

Add the detailed cellular structures of the layers of the intestine to the DRAWING already started, labeling all parts correctly.

On the slide with the cross section of the earthworm observe that the blood vessels appear as hollow, rounded, or irregular cavities bounded by delicate walls. The **dorsal blood vessel** is dorsal to the typhlosole; the **ventral blood vessel** is ventral to the intestine; the **subneural vessel** is ventral to the nerve cord; and the **lateral (neural) vessels** are at either side of the nerve cord.

Add these details to the DRAWING previously started, labeling correctly.

DRAW the ventral nerve cord in its correct position and label.

Leeches (class Hirudinea)

The flattened bodies of leeches ("blood suckers") have **anterior** and **posterior suckers** for attachment and chitinous **jaws** to secure blood from their victims. They have 34 true **body segments** (usually) with each one subdivided into several **false grooves.** There are no bristlelike setae. Annelid characteristics include a series of excretory **nephridia,** ganglionated **ventral nerve cord,** reproductive **gonads** in a **true coelom** which is reduced by connective tissues and muscles. Both sexes are in the same animal (monoecious). **Copulatory organs** on the ventral surface assist in cross fertilization. Respiration, circulation, and digestion occur in much the same way as in other annelids.

DRAW a leech properly labeled to show as many structures as possible.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficient to give accurate, pertinent information? If you think you made errors what were the reasons for making them?

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified from the available evidence? RECORD additional conclusions which might be derived from your studies and which may not be directly associated with the problems. Be sure these conclusions are correct in the light of the collected information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure pertinent, reliable information. Repeat any observations or interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Animals with soft bodies and hard shells—mollusks (phylum Mollusca)

1. Problems

Are mollusks noted for their so-called soft bodies and hard limy shells (the latter being internal or absent in some species)? Is locomotion usually accomplished by some type of muscular foot? Is there a specialized kind of "head-foot" in such types as squids? Is respiration accomplished by well-developed lungs (in terrestrial forms) or gills (in aquatic types)? Do such types as snails and squids have rather well-developed sensory equipment? Do certain types of mollusks have tubular siphons whereby water may be expelled in a jetlike manner? Do mollusks characteristically have some type of mantle by which the shells are secreted? In general do mollusks possess bilateral symmetry with certain parts being asymmetrical in such forms as snails? Do they possess a true coelom even though it may be reduced? Do mollusk bodies possess segmentation? Do all the tissues arise from three embryonic germ layers?

2. Preliminary observations and pertinent data and information

RECORD all the accurate information which you have concerning mollusks which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Not all types of mollusks will be studied nor will detailed studies be made of all the structures and functions of the three selected representatives. Review some of the characteristics of clams, snails, and squids in the text.

Study living specimens, preserved materials, prepared slides, projected slides, and museum preparations, as suggested by the instructor. Study clams, snails, and squids very carefully, observing the characteristics of each. Record the characteristics for each animal in the accompanying TABLE. Make such labeled DRAWINGS as suggested by the instructor.

CLAMS

Shell. A pair of limy **valves** (bivalved), each showing concentric, successive **lines of growth.** The shell has an outer **horny layer;** a middle layer of **calcium carbonate;** and an inner, **iridescent** layer of **nacre (mother-of-pearl).**

Mantle and siphons. One lobe of the **sheetlike mantle** adheres to the inner surface of each valve, and the 2 mantle lobes form a **mantle cavity** which encloses the body. Posteriorly the mantle is modified to form a short, tubular, muscular, **dorsal excurrent (exhalent) siphon** and a short, muscular, **ventral incurrent (inhalent) siphon** to regulate the circulation of water.

Foot. A **hatchet-shaped** muscular **foot** may extend between the 2 valves for burrowing.

Head. No head.

Respiration. One pair of thin **gills** on each side of the foot; each gill has 2 platelike **lamellae** consisting of many filamentous **gill bars** which are supported by **chitinous rods.** Cross partitions between the lamellae divide the gill into numerous **water tubes** through which water passes by the action of **cilia.**

Symmetry. **Bilateral** (2 similar parts).

Sexes. **Dioecious** (sexes in separate individuals) usually.

SNAILS

Shell. Usually one limy, coiled **shell** (univalved).

Mantle and siphons. A **mantle** surrounds the internal organs (visceral mass) and secretes the shell; there are no siphons.

Foot. A flat, muscular **foot** for creeping.

Head. A distinct **head** with **radula** for rasping foods; paired **eyes** and sensory **tentacles.**

Respiration. **Lungs** (in terrestrial types); **gills** (in aquatic types).

Symmetry. **Bilateral** (head and foot); **asymmetry** (visceral mass with shell).

Sexes. **Monoecious** or **dioecious** (depending on the species).

SQUIDS

Shell. A **feather-shaped plate** ("shell") called the **pen** is just beneath the skin of the back near the anterior end.

Mantle and siphons. A thick **mantle** encloses the internal organs in a **mantle cavity** and ends just back of the head, with its free margin being called the **collar.** A thick, cone-shaped **siphon** beneath the collar propels water outward in a jetlike manner.

Foot. Modified into a **"head-foot."**

Head. The **"head-foot"** has a **radula** for rasping; two powerful chitinous **jaws;** paired **eyes;** 8 to 10 **tentacles** ("arms") with **suckers.**

Respiration. Paired internal **gills.**

Symmetry. **Bilateral.**

Sexes. **Dioecious.**

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and detailed to give accurate, pertinent information? Would additional studies be highly desirable? If you think you made errors, give reasons why you made them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they justified and valid as based on the available evidence? Record additional conclusions which might be derived and which might not be directly associated with the problems. Be sure that all conclusions are based on sufficient, accurate evidence.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat any observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Name ______________________

Section ______________________

Date ______________________

ANIMALS WITH SOFT BODIES AND HARD SHELLS—MOLLUSKS

	Clams (class Pelecypoda)	Snails (class Gastropoda)	Squids (class Cephalopoda)
Shell			
Mantle and siphons			
Foot			
Head			
Respiration			
Symmetry			
Sexes			

Animals with spiny skins—echinoderms (phylum Echinodermata)

1. Problems

Should echinoderms be classed high in the scale of animal life in spite of certain characteristics, including radial symmetry in their adult stages? Do the bilaterally symmetrical larval stages resemble the larvae of certain lower chordate animals, and might this explain, in part, some relationship with vertebrate animals? Are echinoderms characterized by a unique water vascular system including numerous tube feet? Do various echinoderms possess calcareous plates (ossicles) with spines, which may be movable or fixed? Do sensitive, pincerlike pedicellariae perform important functions in many types of echinoderms? Is the respiratory system well developed, as illustrated by numerous dermal branchiae ("skin gills") in starfishes, and branched, pouchlike gills in sea urchins?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you may have concerning echinoderms which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Not all types of echinoderms will be studied, nor will detailed studies be made of all the structures and functions of the selected representatives. Review some of the characteristics of starfishes and sea urchins in the text.

Study preserved materials, prepared slides, projected slides, and museum preparations as suggested. Study starfishes and sea urchins very carefully, observing the characteristics and RECORD for each animal in the accompanying TABLE.

The **water vascular system** is unique for echinoderms and may be described briefly as follows. A porous **madreporite plate** (upper, aboral surface) permits the entrance of sea water into a **stone canal** which connects with a **ring canal** surrounding the mouth (lower, oral surface). Leading from the ring canal are five **radial canals** (one in each arm), each with rows of muscular **tube feet.** By regulating the water pressure within the system the tube feet may be attached or freed, thereby assisting in locomotion, securing of foods (such as oysters), etc.

DRAW the water vascular system of a starfish (preferably from one with the system injected with a colored material). Label all parts correctly.

STARFISH

Body. Star-shaped with 5 free **arms** attached to a central disk.

Skeletal plates. **Calcareous plates** which are movable but connected together by muscle and connective tissues; supplied with **spines.**

Ambulacral grooves. Five on the oral (under) surface.

Water vascular system with tube feet. Two to 4 rows of muscular **tube feet** with **suckers,** located in the ambulacral groove of each arm.

Madreporite plate. Porous, present on the aboral side, and connected with the water vascular system.

Pedicellaria. Pincerlike **jaws** which surround the spines.

Respiration. Soft, saclike **dermal branchiae** ("skin gills") on the aboral surface of the arms.

Symmetry. **Radial,** in adults, with **5 antimeres** (parts). (Sometimes considered as biradial.)

Sexes. **Dioecious** (sexes in separate animals).

SEA URCHIN

Body. Globe-shaped with a compact, limy shell ("test") of **fused plates** and without free arms.

Skeletal plates. Ten pairs of **columns of calcareous plates** bearing long, **movable spines.** Five pairs of these columns are homologous with the 5 arms of the starfish and with **pores** for the tube feet.

Ambulacral grooves. Covered with plates (ossicles).

Water vascular system with tube feet. Rows of long **tube feet** with **suckers** and which extend outward through rows of pores in the shell.

Madreporite plate. Porous, present on the aboral surface, and connected with the water vascular system.

Pedicellaria. With **3 jaws** and mounted on long stalks.

Respiration. Ten branched, pouchlike **gills** around the mouth.

Symmetry. **Radial,** in adults, with **5 antimeres.** (Sometimes considered as biradial.)

Sexes. **Dioecious.**

Make DRAWINGS of a starfish and sea urchin, showing such structures as may be desirable to remember them more easily.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently detailed and extensive to supply accurate, pertinent information? Would additional studies be desirable for supplying evidence? If you think that you made errors, give reasons why you did.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the available evidence? Record additional conclusions which might be derived and which might not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Name ______________________

Section ______________________

Date ______________________

ANIMALS WITH SPINY SKINS—ECHINODERMS (PHYLUM ECHINODERMATA)

	Starfish (class Asteroidea)	**Sea urchin (class Echinoidea)**
Body		
Calcareous skeletal plates (ossicles)		
Ambulacral grooves		
Water vascular system with tube feet		
Madreporite plate		
Pedicellaria		
Respiration		
Symmetry (in adults)		
Sexes		
Miscellaneous		

Animals with jointed appendages and an exoskeleton of chitin—arthropods (phylum Arthropoda)

A. Survey of the classes of the phylum Arthropoda

1. Problems

Even though all arthropods have certain characteristics in common, are there differences whereby they may be distinguished and classified? What characteristics do members of the phylum **Arthropoda** have which are improvements over lower animals? In what specific respects have definite improvements been made? How can jointed appendages be advantageous? In what ways is a flexible, chitinous exoskeleton an improvement? In general, are sensory equipments more highly developed in arthropods? When wings are present, how are they beneficial? What is the developmental status of the respiratory system as illustrated by arthropods? Do members of the various classes of arthropods show an efficient differentiation as regards structures and functions? As we study animals from the lower to the higher forms, has there been an increased ability to locomote successfully? What advantages, or disadvantages, might efficient means of locomotion be to an animal?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you have concerning arthropods which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Not all types of arthropods will be studied nor will detailed studies be made of all the structures and functions of the selected representatives.

Study such representative crustaceans, centipedes, millipedes, insects, and arachnids, as supplied by the instructor, noting carefully all characteristics, but particularly those to be filled in the accompanying TABLE. Actually observe these characteristics and do not merely copy information from other sources. Be familiar with these traits so that you may use them in the identification of unknown specimens.

Make such labeled DRAWINGS as may be desirable to remember certain facts.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and detailed so as to supply accurate, pertinent information? What additional studies do you suggest to supply sufficient additional data? If you think you made errors, give reasons why they were made.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretations of the collected information? Are they justified and valid as based on the available evidence? RECORD additional conclusions which might be derived which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Name ______________________

Section ______________________

Date ______________________

SOME CLASSES OF PHYLUM ARTHROPODA

	Crustacea	Chilopoda	Diplopoda
Examples	Crayfishes, lobsters, shrimps, crabs, barnacles, water fleas, sow bugs, etc.	Centipedes	Millipedes
Antennae			
Legs			
Wings			
Respiration	Gill-breathing	Tracheal (air-breathing)	Tracheal (air-breathing)
Habitat	Aquatic for most species (few parasites)	Terrestrial (moist places)	Terrestrial (moist places)
Miscellaneous	Body composed of head, thorax, and abdomen; head and thorax may be fused into cephalothorax	Long, slender, subflattened dorsoventrally; with 15 to 173 segments; swift moving	Long, slender, subcylindrical body; with 25 to 100 segments; slow moving

Name

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SOME CLASSES OF PHYLUM ARTHROPODA (cont'd)

	Insecta	Arachnoidea
Examples	Beetles, flies, butterflies, moths, grasshoppers, crickets, cockroaches, honeybees, ants, wasps, termites, true bugs, dragonflies, etc.	Spiders, scorpions, horseshoe "crabs," mites, ticks, daddy-long-legs, etc.
Antennae		
Legs		
Wings		
Respiration	Tracheal (air-breathing)	Tracheal and book lungs (air-breathing)
Habitat	Terrestrial (some live in water)	Terrestrial
Miscellaneous	Body composed of head, thorax and abdomen; wings, if present, attached to thorax; legs attached to thorax	Head and thorax fused into cephalothorax; no true jaws but pair of "nippers"

Animals with jointed appendages and an exoskeleton of chitin—arthropods (phylum Arthropoda) (cont'd)

B. Economic entomology—economic insects

1. Problems

Of the thousands of species of insects, are there many which are harmful (detrimental), a few which are beneficial, and a great majority which are neither? May an insect be harmful in one stage of its life cycle and harmless in another stage? May different types of insects be controlled in various ways because of (a) differences in their mouth parts, by means of which they secure foods and poisons; (b) differences in methods of respiration, thus influencing the effectiveness of poisonous gases and dusts; (c) differences in the type of metamorphosis from the egg to the adult stage, in which certain stages might be or might not be easily killed; and (d) differences in hosts or habitats in which some might be killed easily in certain hosts or habitats by one method but not killed by another method? May a certain insect be beneficial to man because it destroys other insects but at the same time be harmful to the insect being destroyed? Are the detrimental insects members of a great number of the orders of the class Insecta or are they limited to a few of the orders? May two species of insects which in general resemble each other (that is, ladybird beetles and Mexican bean beetles) be quite opposite in their economic importance? May certain stages of some insects such as scale insects (order Homoptera) not appear like insects in the commonly accepted sense? What roles have modern insecticides played in the control of harmful insects? Have some of them also destroyed beneficial types?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you have concerning the economic importance of insects, including only that which you know to be true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Not all insects of economic importance can be studied nor will detailed studies be made of all the structures, functions, and life activities of the selected representatives.

One of the most important problems in economic entomology is to learn to distinguish between beneficial and injurious insects. **Learn to recognize each of the following insects.**

BENEFICIAL INSECTS

Ladybird beetles. Examine carefully and learn to recognize the following common species of ladybird beetles. Why are they so named? Beetles belong to the order Coleoptera.

1. The 9-spotted ladybird; 9 black spots on light brown elytra (sheathlike wing)
2. The 2-spotted ladybird; 2 black spots on light brown elytra
3. The 13-spotted ladybird; 13 black spots on light brown elytra
4. The convergent ladybird; 12 black spots on light brown or yellow elytra; 2 white convergent lines on the region just anterior to the elytra
5. The twice stabbed ladybird; 2 brown spots on very dark elytra
6. The spotted ladybird; 10 black spots on orange brown elytra
7. The unspotted ladybird; no spots on a brown or yellow elytra
8. The parenthesis ladybird; 5 dark spots on yellowish elytra; the 2 posterior spots are shaped like parentheses, as ( ).

How can you distinguish these common species? Where have you observed any of these beetles? What were they doing? The larvae of these beetles are dark and elongated and taper at the posterior end. These insects are very active and live on scale insects, aphids, and eggs and larvae of other insects. Both the larvae and adults are therefore considered beneficial. How do they destroy their prey?

Ground beetles. Study several common species of ground beetles (family Carabidae). How do these forms differ from the ladybirds? Have you ever observed the ground beetles on the ground or on trees? The adult stage is especially beneficial, destroying insect pests in the ground and on trees. What kind of mouth parts do they have? How do they destroy their prey?

Damsel bugs. The damsel bugs (order Hemiptera) are usually found on leaves and feed on small insects, especially aphids. State the size, color, type of mouth parts, etc. Is there anything characteristic about the anterior part of the head? Is this important? Why?

Robber flies. Learn to recognize robber flies (order Diptera). These are flylike insects, rather large, and with a more or less slender abdomen. In some species, however, the abdomen may be stout and bumblebee-like. The vertex or top of the head between the eyes is hollow. This is a distinguishing characteristic.

Tiger beetles. The tiger beetles (family Cicindelidae) have their antennae inserted in front of the head above the base of the jaws. The color of these beetles is quite variable with the species. Some are metallic green or bronze with yellow bands or spots, whereas others are black or grayish white. How would you recognize a tiger beetle. How are they beneficial?

PARASITIC INSECTS

Parasitic insects vary quite materially in size. Some are very small so as to be parasitic on insect eggs, whereas others are large and attack large caterpillars, inserting their eggs inside the bodies of the caterpillars and allowing their young to develop there, thus destroying the caterpillar. Could this be of economic importance? How?

Study carefully some species of ichneumon flies (order Hymenoptera) and tachina flies (order Diptera). How can you distinguish them? How are these species of economic importance?

INSECTS INJURIOUS TO STORED GRAINS

Most of our common and important pests of stored grain and cereal products belong to the orders Coleoptera and Lepidoptera.

Saw-toothed grain beetle. This is a most common beetle in all kinds of stored grain and causes much loss. Why is it so named? Describe its color, size, and its thorax. How does it produce its damage? What are the methods of control?

Tenebrio beetle or mealworm. The larval and adult stages injure grain. What is the size, color, and general appearance? Give control methods.

Angoumois grain moth. Describe in detail the adult and larval stages of the angoumois grain moth (order Lepidoptera). How and by what stage is the damage produced? Look up the life cycle of this form in any text on economic entomology.

INSECTS AFFECTING GRASSES, GRAINS, AND FORAGE CROPS

Click beetle. The click beetle larvae are known as wireworms. Why are the larvae so called? What type and how do the wireworms produce damage? Learn to recognize the "click beetles" in the field. Describe the general appearance of the wireworm. What crops are attacked? Under what conditions of cultivation or cropping do they cause serious damage? With this as a basis formulate control measures.

White grub. The white grub is the larva of the common June beetle which is so prevalent around lights on summer nights. What are the habits of the grub? How can it be recognized? What part of the plant is affected and what is the nature of the injury? How can we control this pest? Where and in which stage of the life cycle is the winter spent? Is a knowledge of the habits of importance in the control?

Cutworms. The cutworms are the larvae of the owlet moths (order Lepidoptera; family Noctuidae). Why are they called cutworms? How would you recognize their work in the field? Describe the cutworm in detail. Describe a cutworm moth in detail. Give measures for the control of cutworms.

Locusts. "Differential" locust and "red-legged" locust (order Orthoptera) are nonmigratory species and are quite common in some localities. Learn to recognize each. Look up the life cycle. List the means of control.

Tarnished plant bug. The tarnished plant bug (order Hemiptera) is widely distributed throughout the world. List as many of its host plants as possible. Describe in detail the adult and nymph stages. How and what type of injury is produced? Describe the complete life cycle, telling where each form is to be found. What measures might prove best in their control?

Leafhoppers. The leafhoppers (order Homoptera) are abundant in pastures, meadows, and grain fields. Learn to recognize them. List their distinguishing characteristics. How and what type of injury is produced? How can they be controlled?

Chinch bug. The chinch bug (order Hemiptera) during its development passes through 4 instars (immature stages) before reaching the adult stage. Describe the adult in regard to size, coloration, and general appearance. Study the nymph stage in a similar manner. What measures of control are best?

Hessian fly. Describe the size, shape, and color of the egg, larval, pupal, and adult forms of the Hessian fly (order Diptera). Where are each of these stages usually found? Describe the type of injury due to this pest. What control is used?

INSECTS INJURIOUS TO CORN

Not all insects found in cornfields are injurious, some being only visitors, whereas others are beneficial and feed on other insects, such as plant lice.

Corn borer. Learn to recognize the egg, larval, pupal, and adult stages of the European corn borer (order Lepidoptera). How can their presence in the field be recognized? How far has the corn borer spread in this country? Which stage of the life cycle produces the damage? List the measures of control.

Root worm. The Southern corn root worm is the larva of a leaf beetle (order Coleoptera; family Chrysomelidae). How can you distinguish the adult and larval stages? What type of damage is produced? How can they be controlled?

INSECTS AFFECTING POTATOES AND TOMATOES

Colorado potato beetle. Learn to recognize this form in the larval, pupal, and adult stages. Which stages damage? What parts of the plants are attacked? Where do they pupate? What are the control methods?

Potato or apple leaf hopper. This pest causes "hopperburn" or "tipburn" of the leaves. The insects (order Homoptera) are tiny and feed on a variety of plants. What is the size, color, and general appearance? What type of mouth parts does this form have? What is the type of injury? How does this pest overwinter? Give control measures.

INSECTS AFFECTING BEANS AND PEAS

Weevils. Pea and bean weevils (order Coleoptera): examine both and their work. How do they differ? Do they affect only stored beans or peas? How are they controlled?

Mexican bean beetle. Examine larvae, pupae, and adults. How would you recognize each stage? Where do they pupate? What is the typical injury produced? What are the most successful means of control? What is the distribution of this beetle in the United States?

INSECTS AFFECTING FRUITS

Grape phylloxera. This is an aphid (order Homoptera). What part of the plant is affected? What damage is done? Study the summer stage in a leaf gall. Have you ever observed similar structures on grapevines or other plants? Read in some textbook about plant galls produced by insects.

Scales. The San Jose scale (order Homoptera) and oyster shell scale are very common types of scale insects. How can you distinguish these two species? Give shape, color, and comparative size of each. Where is the insect? How do scale insects injure plants? How can they be controlled?

Plum curculio. The plum curculio (order Coleoptera) is an important pest of many fruits. In what stage does it injure the fruit? Does it injure the plant? Describe a typical injury. How can the insect or its injury be recognized in the orchard? How can this pest be controlled?

INSECTS AFFECTING HOMES

Termites. These insects (order Isoptera) may be very destructive of wooden structures. Study specimens of the various castes so that you are able to recognize each. Study the life cycle so as to be able to describe it in detail. Why are termites becoming a greater menace than in former years? What are methods of prevention and probable control?

Roaches. Roaches (order Orthoptera) are found as pests in certain places where foods are available. Study specimens of the different species found in your community. What control measures are useful?

Ants. The true ants (order Hymenoptera) are not to be confused with termites, which are not ants at all. Study these two kinds of insects so as to be able to distinguish between them. What measures are useful in controlling each kind?

Flies. These insects (order Diptera) are common household pests and may spread disease germs especially to foods which they contact. Where do flies breed and is this a factor in their control?

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and representative so as to supply accurate, pertinent information? Why do you say so? What additional studies might be made to supply sufficient additional data? If you think you made errors, give reasons why you made them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the available information? RECORD additional conclusions which might be derived which might not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Animals with jointed appendages and an exoskeleton of chitin—arthropods (phylum Arthropoda) (cont'd)

C. Common insects—grasshopper and honeybee

1. Problems

Are some structures of insects highly specialized so that they are able to perform certain functions efficiently and thereby live quite successfully in their attempts to adapt themselves to their environments? Do chitinous exoskeletons serve useful purposes on insects? Are there two principal types of mouth parts in insects, namely (a) mandibulate (with jaws or mandibles) for chewing and (b) suctorial (for sucking or siphoning), and which may be modified sometimes or even combined? Is the number of segments in the legs of insects usually the same, there being some variations in the sizes and shapes of the individual segments in different species? Are the legs of some insects, such as honeybee workers, modified to perform specialized work? Is the posterior abdomen of a worker honeybee supplied with a stinger, poison sacs, etc.? Do honeybees and grasshoppers possess paired compound eyes on which images may be recorded? Do some insects, such as honeybees and ants, live in colonies, composed of different castes, and thereby develop a highly organized communal life? Do some insects possess sexual dimorphism in which the two sexes may be distinguished by differences other than the sex organs? Do insects possess metamerism in both larval and adult stages, even though some of the segments may be fused in adults? Do most insects undergo a type of metamorphosis in their development from the egg to the adult? Do insects periodically shed their exoskeleton by a process called ecdysis (moulting)? Are insects able to propagate themselves more or less successfully and adapt themselves to their environments more or less efficiently because they usually (a) produce large numbers of offspring, (b) possess abilities to locomote from centers of dispersal (place of birth), (c) possess abilities to adapt themselves to various environmental conditions, (d) have rather well-developed nervous systems and sensory equipments, (e) possess a protective exoskeleton of chitin, and (f) in certain species undergo such a type of metamorphosis that some of the stages may serve as a protection during these embryonic times?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you may have concerning grasshoppers or honeybees, or both, which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods whereby you may secure additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

In order to secure more detailed information regarding the structures and functions of representative insects it may be desirable to study a common grasshopper, a common honeybee, or both.

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GRASSHOPPER (Phylum Arthropoda; Class Insecta; Order Orthoptera; Genus *Romalea* [ro-mal′ e a] [Gr. *rhomaleos*, strong body]).

GENERAL CHARACTERISTICS OF GRASSHOPPER

Observe the shape, color, and general external anatomy, noting how each of these may help in its "struggle for existence." Observe the 3 main divisions of the insect: (1) the **head,** (2) the **thorax,** bearing 3 pairs of **legs** and 2 pairs of **wings,** and (3) the **abdomen,** composed of a number of serially arranged segments known as **somites** or **metameres.** Are all 3 divisions of the insect segmented? Could they originally have been segmented but have become fused in the adult? Observe the hard, chitinous **exoskeleton.**

Head of grasshopper. Observe that the parts of the head may be divided into (1) fixed parts and (2) movable parts. The fixed parts include the various portions of the head, the **compound eyes,** and the **ocelli (simple eyes).** The pair of large, brown, oval **compound eyes** are near the top of the head. Why are they so situated? Study the external cutical of a compound eye, noting the hexagonal-shaped **facets.** The facets are the external surfaces of the numerous units of the compound eye known as **ommatidia** (singular, ommatidium). Each ommatidium acts as a unit and is able to record a complete image of an object being observed. The 3 **ocelli** are located in depressions; one is located in a depression at the base of each antenna; the third is located in a depression in the middle-front portion of the head. Lines drawn transversely across the head from the upper and lower thirds of the compound eyes would cross the ocelli.

The movable parts of the head include (1) the pair of jointed **antennae** located in front of the compound eyes and (2) the **mouth parts.** Identify the mouth parts as follows: (a) the **labrum** or movable upper lip on the extreme lower border of the front part of the head, (b) the pair of hard, tooth-bearing **mandibles** which may be observed by raising the labrum (they appear on the sides of the head as triangular areas), (c) the pair of **maxillae** back of the mandibles, each bearing a jointed **maxillary palp** or **feeler,** (d) the **labium** or lower lip on the underside of the head, also bearing jointed **labial palps,** and (e) the tonguelike **hypopharynx** lying between the maxillae which may remain in the middle of the mouth after the other mouth parts are removed.

Remove the mouth parts described above in that order. Place them so as to form a rectangle—the labrum at the upper side, the mandibles and maxillae on the sides, the labium at the bottom, and the hypopharynx in the center.

DRAW each of the mouth parts removed and arranged as suggested. Label all parts correctly. Why are these mouth parts called chewing (**mandibulate**) mouth parts?

Thorax (detailed study). The **thorax** is composed of 3 parts: (1) the **prothorax,** bearing a pair of **prothoracic legs,** (2) the **mesothorax** (middle thorax), bearing a pair of **mesothoracic legs** and a pair of leathery **mesothoracic forewings,** and (3) the **metathorax,** bearing a pair of **metathoracic legs** and a pair of **metathoracic hindwings.**

PROTHORAX. Note that the hood-shaped **pronotum** on the dorsal side extends forward over the head to protect the neck and backward over the mesothorax to protect the base of the wings.

The **prothoracic leg** has 5 divisions: (1) the **coxa** nearest the body, (2) the next division, the **trochanter,** which is somewhat fused with (3) the larger, stronger **femur,** (4) the long, slender **tibia,** and (5) the **tarsus** which is composed of 3 segments and bears a pair of **claws** known as **ungues.**

The disklike **pulvillus** lies between the claws and serves for attachment purposes.

DRAW the prothorax (side view), showing all parts correctly labeled.

MESOTHORAX. This segment bears the leathery **mesothoracic forewings** which are really **wing covers (tegmina).** Observe the arrangement of the **veins** in the wings. The dorsal part of the mesothorax where the wings are attached is known as the **tergum,** the sides are known as **pleura,** and the ventral part as the **sternum.** These 3 terms apply to each of the 3 segments of the thorax. Observe the **mesothoracic spiracle,** an opening in the soft integument on the side of the thorax under the posterior border of the pronotum. Observe the **metathoracic spiracle** on the suture which separates the mesothorax and the metathorax. Both spiracles are guarded by **lips** and serve as entrances to the interior respiratory tubes which carry oxygen to various parts of the body.

DRAW the mesothorax (side view), showing all parts correctly labeled.

METATHORAX. Observe the folded, membranous, **hindwings** and the large **jumping legs** which are similar in construction to the other legs, except larger. Note each of the 5 divisions.

DRAW the metathorax (side view), showing all parts correctly labeled.

Abdomen (detailed study). In the **first** abdominal segment observe the oval **tympanic membrane** of the **ear** which covers the internal auditory sac of hearing. The tympanic membrane is bounded by a crescent-shaped elevation. The first abdominal segment does not reach down to the sternum because of the jumping legs. Observe the 10 pairs of openings, called **spiracles,** on the lower sides of the abdomen, which open into the respiratory system. Note that there are some **complete segments** and several **partial segments** near the posterior end. These posterior, partial segments make up the **anal appendages.** Contrast these anal appendages in the two sexes. The tip of the abdomen in the female is somewhat pointed unless the pincerlike **ovipositors** are spread to deposit eggs. Carefully contrast the rounded structure of the anal appendages in the male with those of the female.

DRAW the abdomen (side view), showing all parts correctly labeled.

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HONEYBEE (Phylum Arthropoda; Class Insecta; Order Hymenoptera; Genus *Apis* [a'pis] [L. *apis,* bee]).

GENERAL CONSIDERATION OF HONEYBEE

Three castes of honeybees are found in an active hive; namely, one fertile female, the **queen;** several thousand infertile females, the **workers;** and several hundred fertile males, the **drones.** Study these three types, noting differences in size and shape of the abdomen. What other differences do you observe?

Study a **worker bee** with a hand lens or dissecting microscope, noting the **head, thorax,** and **abdomen.** Observe the **exoskeleton of chitin.** What are the functions of such an exoskeleton? Study the paired, jointed **antennae** which project from the anterior surface of the head. Observe the location of the large **compound eyes.** Why are they so located?

Observe that the thorax is divided into the **prothorax, mesothorax,** and **metathorax,** respectively. The prothorax bears a pair of prothoracic legs. The mesothorax bears a pair of mesothoracic legs and a pair of mesothoracic wings. The metathorax bears a pair of metathoracic legs and a pair of metathoracic wings. Why are the wings borne on the middle and the last thoracic segments rather than elsewhere?

Study the **abdomen,** noting that it is composed of segments. The exoskeleton of each segment is made up of a dorsal **tergum** and a ventral **sternum.** Observe the **anus,** the **genital pore,** and the **sting** at the posterior end of the abdomen.

DRAW the worker bee (side view) enlarged 10 times and labeled.

Head of worker honeybee (detailed study). Remove the head, noting (1) the large **compound eyes** on either side of the head, (2) the three **ocelli** (simple eyes) in the form of a triangle on the dorsal, anterior part of the head, (3) the pair of jointed **antennae** just below them on the anterior surface, and (4) the **mouth parts** consisting of (a) the **narrow upper**

lip (labrum) attached to the front of the head, (b) a pair of chitinous **mandibles** (jaws) just behind the narrow upper lip which move from side to side in kneading wax to make honeycomb, (c) next, a pair of rather broad, bladelike **maxillae** with sensitive **maxillary palps,** and (d) next, the **lower lip (labium)** with its pair of long, **labial palps.** In the bee the maxillae and labial palps form a long tubelike **proboscis** through which projects a longer, flexible **tongue** or **glossa (ligula).** The tip of the tongue has an enlarged, spoon-shaped **labellum (bouton).** The proboscis and tongue suck **nectar** from flowers.

DRAW an enlarged, anterior view of the head, showing all parts labeled.

Thorax of bee (detailed study). The paired legs are named in accordance with the segment to which they are attached. The mesothoracic and metathoracic segments each bear a pair of **wings** in addition to the legs. The wings consist of a membranous, transparent material supported by heavier chitinous structures known as **veins.** The two wings on the same side of the body may be united to each other by means of a row of **hooks** which are present on the anterior margin of the hindwing and which are inserted in a receptacle on the posterior margin of the anterior or front wing.

REMOVE a wing and study its venation.

With a forceps carefully remove the left **prothoracic leg,** being sure that you secure all the joints near the body. Mount and examine, noting the 5 parts of which it is composed. Beginning with the one attached to the body they are designated as follows: (1) **coxa,** (2) **trochanter,** (3) **femur,** (4) **tibia,** and (5) the 5-jointed **tarsus.** Note the **pollen brush,** which consists of a number of curved bristles extending on one side from the distal end of the tibia. The pollen brush is used to brush up the pollen loosened by the coarser spines. Attached to the opposite or inner surface of the tibia nearby is a flattened movable chitinous structure, the **velum,** which resembles in shape the blade of an old-fashioned razor. The velum joins with a crescent-shaped indentation known as the **antennae comb** on the inner side of the first tarsus. The antennae comb contains a number of toothed structures as in a comb. The velum and the antennae comb form the **antennae cleaner.** The antennae are held in position by the velum and are then drawn through the curved antennae comb and cleaned. On the outer edge of the large first joint of the tarsus (called the **metatarsus**) there is a row of stiff bristles projecting a considerable distance beyond the surface of the leg and forming the **eyebrush.** The eyebrush is used in brushing the hairs projecting from the compound eyes. The middle three joints of the tarsus are small and similar to each other in structure. The last or distal tarsus bears **claws** and sensory or tactile hairs. Between the claws is a comparatively large, fleshy **structure,** the **pulvillus,** which forms a sticky liquid, thus enabling the animal to cling to smooth surfaces.

DRAW a prothoracic leg to show the structures observed. Label.

Remove, mount, and study as before the left **mesothoracic leg.** Observe the **pollen spur,** which is a long chitinous rod on the distal end of the tibia near the joint with the first tarsus **(metatarsus).** It has about the same position as the velum on the prothoracic leg. The pollen spur is used to dislodge the pollen which the bee has collected and stored in its special pollen basket to be described later. It is also used to clean the wings. Observe the presence of another **pollen brush** similar in structure to that on the prothoracic leg. Does the first tarsus (metatarsus) of the mesothoracic leg contain an eyebrush and antenna comb?

DRAW the mesothoracic leg to show the above structures. Label.

Remove and study the **metathoracic leg.** Observe (1) the **pollen basket,** a large concavity on the outer surface of the tibia, (2) the row of short, stiff spines **(pecten)** present on the distal end of the tibia, (3) a concave plate **(auricle)** on the first joint of the tarsus (the pecten fits into the auricle on the proximal edge of the tarsus; taken together the two form the **wax pincers**), (4) the **pollen combs** consisting of several rows of regularly arranged bristles, which are present on the inner side of the first tarsus **(metatarsus).** The pollen comb is used to comb the pollen out of the branched hairs of the bee and to transfer it to the pollen basket of the opposite metathoracic leg.

DRAW the metathoracic leg to show the above structures. Label.

Abdomen (detailed study). Remove the last two segments of the abdomen and place on a slide, and with a pair of needles dissect out the **sting.** Note the following: (1) a pair of **barbed darts,** which with the **sheath** form a long, rigid, median structure, (2) a pair of fleshy **sting feelers** on either side of the darts, and (3) the **poison sac** attached to the **poison glands.**

During the process of stinging, the feelers locate a favorable region and then the sheath with its pair of darts (one on either side of the sheath) is forced into the tissues. There is then injected a poison which has been secreted by the convoluted tubular poison glands.

DRAW the sting to illustrate the above structures. Label correctly.

If desirable, study embryonic stages of the honeybee, noting particularly the segmentation, contrasting it with segmentation as modified in the adult.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently detailed and extensive so as to supply accurate, pertinent information? Why do you say so? What additional studies might be made to supply additional desirable information? If you made errors give reasons why you may have made them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they justified and valid as based on the available information? RECORD additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Animals with jointed appendages and an exoskeleton of chitin—arthropods (phylum Arthropoda) (cont'd)

D. Identification and classification (taxonomy) of insects

1. Problem

Do various species of insects possess distinguishing traits whereby they may be identified by the use of a taxonomic key?

2. Preliminary observations and pertinent data and information

RECORD all of the reliable information which you have concerning insects which pertains to the problem, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problem formulate hypotheses from which you may work in its solution. Suggest specific methods which will supply additional information and evidence.

Use several numbered insects and trace them through the key to prove their identity. First use insects whose identity and classification are better known in order to become familiar with the correct use of the key. Later use insects whose exact classification is not known to you, tracing them accurately to their proper order.

In the key start at **A** and, if this description fits, pass on to **B** or **BB**, deciding which of these best fits the specimen being studied. If the description under **B** coincides with that of your specimen, pass on to **C**, **CC**, **CCC**, or **CCCC**. Continue this procedure until the correct order has been reached. If at the beginning the description under **A** does not apply, pass to **AA** (nearer the end of the key) and proceed as suggested above until the correct order is reached.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

In order to know insects better, to secure training in careful observation and in the use of a taxonomic key, it may be desirable to identify such insects as supplied by the instructor.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problem? Were the studies sufficiently extensive to supply accurate, pertinent information? If you think that you made errors, give reasons why they were made.

Text continued on p. 147.

KEY FOR IDENTIFYING THE ORDERS OF THE CLASS INSECTA (INSECTS)

A—Winged insects
- **B**—2 pairs of wings
  - **C**—Mouth parts for chewing (biting)
    - **D**—First pair of wings chitinous (horny); meeting in straight line down the back
      - **E**—Abdomen with pincerlike organ at tip . . . . **Dermaptera** (earwigs)
      - **EE**—Abdomen without pincerlike organ . . . . **Coleoptera** (beetles)
    - **DD**—First pair of wings membranous or leathery
      - **E**—First pair of wings leathery; second pair membranous and folded under first; 2 pairs unlike in structure
        - **F**—Antennae conspicuous . . . . **Orthoptera** (crickets, grasshoppers, roaches, etc.)
      - **EE**—First and second pairs of wings both membranous and alike in structure
        - **F**—Second pair of wings wide, folded lengthwise like fan; first pair narrow; wings usually longer than body; tarsus ("foot") is 3 jointed . . . . **Plecoptera** (stone flies)
        - **FF**—Second pair of wings not folded when at rest; wings usually not longer than body
          - **G**—Chewing mouth parts at tip of deflexed beak
            - **H**—Wings frequently dark spotted; not held rooflike when at rest . . . . **Mecoptera** (scorpion flies)
          - **GG**—Chewing mouth parts but not at tip of beak; no spots on wings
            - **H**—Wings held rooflike when at rest
              - **I**—Wings similar with many cross veins . . **Neuroptera** (Dobson flies, ant lions, lace wings, etc.)
              - **II**—Few cross veins; first pair of wings larger; body of insect louselike . . . . **Corrodentia** (bark lice)
            - **HH**—Wings not held rooflike when at rest
              - **I**—Few veins in wings
                - **J**—Abdomen attached to thorax by thin peduncle . . . . **Hymenoptera** (bees, wasps, winged forms of true ants, etc.)
              - **II**—Wings with finely netted veins
                - **J**—Abdomen with 2 or 3 jointed filamentous appendages (cerci) at tip; abdomen broadly attached to thorax . . . . **Ephemerida** (May flies)
                - **JJ**—Abdomen without filaments at tip; body of insect tusk shaped
                  - **K**—Antennae short, inconspicuous, each wing has slight notch near middle of front margin

Continued on next page.

L—Wings horizontal when at rest . . . **Odonata** (dragon flies)

LL—Wings vertical at side of body when at rest . . . . . . **Odonata** (damsel flies)

EEE—First and second pair of wings long, similar, unfolded and flat and overlap on back when at rest

F—Body is antlike but abdomen is solidly attached to thorax; tarsus ("foot") is 4 jointed . . . . **Isoptera** (winged forms of termites)

CC—Mouth parts for piercing-sucking

D—First pair of wings thickened at base with membranous tips which overlap on back; beak arises from front of head . . . **Hemiptera** (true bugs)

DD—First pair of wings not thickened at base but membranous and similar throughout; wings held rooflike at sides of body; beak arises from posterior, ventral part of head . . . . **Homoptera** (cicadas, leaf hoppers, tree hoppers, winged forms of aphids, winged forms of male scale insects)

CCC—Mouth parts for sucking but not for piercing

D—Wings usually broad; body and wings with scales

E—Antennae with knoblike enlargement at tip; insects usually diurnal in habits . . . . **Lepidoptera** (butterflies)

EE—Antennae with knoblike enlargement near tip and recurved structure at tip; usually jump ("skip") in their diurnal habits . . . . **Lepidoptera** (skippers)

EEE—Antennae feathery; usually nocturnal insects . . . . **Lepidoptera** (moths)

DD—All wings narrow, fringed with long hairs but without scales

E—Feet with bladderlike structure instead of claws . . . . **Thysanoptera** (thrips)

CCCC—Mouth parts poorly developed (rudimentary)

D—All wings membranous and clothed with fine hairs; many longitudinal veins in wings . . . . **Trichoptera** (caddis flies)

BB—One pair of wings; knoblike halteres or "balancers" (modified wings) take place of second pair of wings; wings naked or with microscopic hairs

C—Mouth parts for piercing-sucking . . . . **Diptera** (flies, gnats, mosquitoes, crane flies, etc.)

CC—No mouth parts . . . . **Homoptera** (males of certain scale insects)

AA—Wingless insects

B—Mouth parts for chewing (biting)

C—Mouth parts retracted within head

Continued on next page.

D—Abdomen with more than 6 segments	**Thysanura** (bristle-tails, silver fish)
DD—Abdomen with 6 segments	**Collembola** (spring-tails, "snow fleas")
CC—Mouth parts not retracted within head	
D—Abdomen and thorax joined by slender peduncle or petiole .	**Hymenoptera** (wingless forms of true ants)
DD—Abdomen and thorax broadly joined	
E—Body somewhat antlike	**Isoptera** (certain castes of termites)
EE—Body louselike, soft, small, yellowish	
F—Antennae nearly as long as body; legs large	**Corrodentia** (book lice)
EEE—Body louselike, small, flattened horizontally	
F—Antennae short; often hidden in groove; legs not large	**Mallophaga** (biting lice)
EEEE—Body somewhat beetlelike, flat, narrow	
F—Pair of pincers at tip of abdomen	**Dermaptera** (wingless earwigs)
BB—Mouth parts for sucking (or may be intermediate)	
C—Feet with bladderlike structures; without claws	**Thysanoptera** (wingless thrips)
BBB—Mouth parts for piercing-sucking	
C—Body small, flattened laterally; spines point backward	**Siphonaptera** (fleas)
CC—Body small, flattened horizontally.	**Anoplura** (true lice)
CCC—Body scalelike or gall-like and covered with powder, wax, etc.	**Homoptera** (certain female scale insects)

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the available evidence? RECORD additional conclusions which may not be associated directly with the problem. Be sure that all conclusions are based on sufficient, accurate information. If you had difficulty in identifying a certain insect, might this be due to variations in that particular specimen, or because of the necessary brevity of such a simple key?

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. How many times did you repeat the attempt to identify each specimen? Was this a sufficient number of times? Why do you say so? Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate information and conclusions.

The lower chordates—protochordates (phylum Chordata)

1. Problems

Are some of the chordates known as protochordates (lower chordates) because they possess certain traits which characterize the phylum Chordata but do not possess the traits of the higher chordates known as vertebrates? What are the primary distinguishing characteristics of chordates? Do all protochordates possess these traits in equal states of development, and may some of the traits be present in the larval stages and not in the adult? Is there an increase in the development of these traits within the protochordate group? How are a dorsal notochord, dorsal nervous system, and paired pharyngeal clefts (slits) advantageous to animals? Why should these animals be classed in the same phylum as fishes, frogs, reptiles, birds, and mammals (including man)?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you may have concerning the protochordates which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Only a few representative lower chordates will be studied, and not many detailed structures and functions will be considered in the representatives selected.

Make careful studies of the protochordates supplied, noting particularly the descriptions and filling in the accompanying CHART. RECORD distinguishing characteristics for each group under the miscellaneous heading. Make careful observations of the characteristics of each type so that you may be able to identify them in the future.

Make such labeled DRAWINGS of protochordates as may be desirable to enable you to remember important facts.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently detailed and extensive so as to supply additional, pertinent information? Which additional studies do you suggest to supply additional data? If you think that you made errors, give reasons why you may have made them.

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PROTOCHORDATES OF THE PHYLUM CHORDATA

Subphylum	Hemichordata	Urochordata	Cephalochordata
Examples	Balanoglossus *(Glossobalanus)*; Dolichoglossus *(Sacchoglossus)*	Sea squirts, Tunicates *(Molgula)*	Amphioxus *(Branchiostoma)*
Notochord	Short and confined to proboscis	Absent in adults; present only in free-swimming tadpolelike larvae	Present along entire length of body and throughout life
Nerve cord	Dorsal and connected to ventral nerve cord by ring	In adults single nerve ganglion with nerves; in larvae dorsal, neural tube in tail, enlarging in trunk, and ending in vesicle ("brain")	Tubular, dorsal, nerve cord along entire body and persisting throughout life; slight anterior, cerebral vesicle ("brain")
Pharyngeal clefts (gill slits)	Several, small, paired gill slits (in respiratory pharynx)	Numerous, ciliated pharyngeal slits (in pharyngeal wall)	100 pairs of gill slits (in pharynx)
Body characteristics and locomotion			
Habitat			
Miscellaneous			

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the available evidence? Why do you say so? RECORD additional conclusions which might be derived which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

The vertebrates (phylum Chordata; subphylum Vertebrata)

1. Problems

Are some of the chordates known as vertebrates because they possess certain traits which characterize the phylum Chordata and also possess some highly developed traits common to the subphylum Vertebrata? What traits do all vertebrates have in common? Do all vertebrates possess those traits in equal states of development, and may some traits be present in embryonic stages and not in adults, as such? In general is there a progressive increase in complexity of structures and functions as we ascend from the class Cyclostomata to the class Mammalia? What do the appendages show as we progress from the lower to the higher vertebrates? What changes occur in the circulatory and respiratory systems in the vertebrate series? Do the body integuments display traits which somewhat fit them for their particular types of life in different environments? Do the members of the different classes of vertebrates possess sufficiently different traits so that they can be classified?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you may have concerning the vertebrates which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems formulate hypotheses from which you may work in their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Not all members of the various classes of vertebrates can be studied, nor will detailed studies be made of all the structures and functions of the selected representatives. Study such materials, charts, models, slides, skeletons, and museum materials, as suggested. Review the characteristics of each class in the text, noting as many of them as possible in the materials suggested for study. Observe these traits carefully so that you may use them in identifying unknown specimens. RECORD as many facts as possible in the accompanying CHART, using additional pages if necessary.

To assist in your observations make careful use of the following information. The **body integuments** of various vertebrates include the following.

(a) Smooth skins without scales
(b) Platelike, placoid scales with spines
(c) Dermal scales of different types
(d) Smooth, moist skins (usually scaleless); many glands
(e) Dry, rough skins usually with epidermal, horny plates (often with bony plates)
(f) Skins with feathers and leg scales
(g) Skins with hair (at some time of life)

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CLASSES OF THE SUBPHYLUM VERTEBRATA

Classes	Cyclostomata (Agnatha)	Elasmobranchii (Chondrichthyes)	Pisces (Osteichthyes)
Examples	Lampreys, hagfishes	Sharks, rays	Bony fishes
Notochord and skeleton	Notochord persists; cartilaginous (and fibrous skeleton)	Notochord persists; endoskeleton entirely of cartilage; separate vertebrae	Notochord may persist in part; skeleton more or less bony which replaces the cartilaginous original
Nervous system	Brain dorsal; nerve cord; 8 to 10 pairs of cranial nerves	Brain dorsal; nerve cord; 10 pairs of cranial nerves	Brain dorsal; nerve cord; 10 pairs of cranial nerves
Gills or lungs	6 to 14 pairs of gills (in gill pouches)	5 to 7 pairs of platelike gills with separate external gill slits; no gill covers (operculum)	Paired gills supported by bony gill arches; gill covers (operculum)
Body integument			
Appendages			
Miscellaneous			

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CLASSES OF THE SUBPHYLUM VERTEBRATA (cont'd)

Classes	Amphibia	Reptilia	Aves
Examples	Frogs, toads, salamanders	Turtles, lizards, snakes, chameleons, alligators, crocodiles	Birds
Notochord and skeleton	Notochord does not persist; endoskeleton mostly bone; ribs present or absent (depending on the species); skull with 2 occipital condyles	Endoskeleton bony; ribs and sternum (breast bone); skull with 1 occipital condyle	Endoskeleton bony; ribs and sternum with a keel; skull with 1 occipital condyle
Nervous system	Dorsal brain and nerve cord; 10 pairs of cranial nerves	Dorsal brain and nerve cord; 12 pairs of cranial nerves	Dorsal brain and nerve cord; 12 pairs of cranial nerves
Gills or lungs	Paired gills or lungs (external gills of larvae may persist throughout life)	Paired lungs throughout life	Paired lungs throughout life; voice box (syrinx) at junction of trachea and bronchi
Body integument			
Appendages			
Miscellaneous			

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CLASSES OF THE SUBPHYLUM VERTEBRATA (concluded)

Classes	Mammalia
Examples	Mammals including man, monkeys, horses, dogs, cats, whales, bats, etc.
Notochord and skeleton	Bony skeleton with some cartilage; ribs and sternum; skull with 2 occipital condyles
Nervous system	Well-developed dorsal brain and nerve cord; 12 pairs of cranial nerves
Gills or lungs	Paired lungs throughout life; voice box consisting of larynx, epiglottis, etc.
Body integument	
Appendages	
Miscellaneous	

The types of **appendages** of various vertebrates include the following:

(a) Unpaired fins with rays of cartilage for support

(b) Paired pectoral and pelvic fins and unpaired dorsal and median fins with fin rays

(c) Paired and unpaired fins with bony or cartilaginous fin rays

(d) Usually 2 pairs of legs (some species legless); some limbs small, often with webbed feet

(e) Usually 2 pairs of legs (none in snakes) with 5 toes

(f) Paired wings (some with vestigial wings); paired hind limbs, typically with 4 toes

(g) 2 pairs of limbs (reduced in some), typically with 5 toes (reduced in many species)

Make labeled DRAWINGS as suggested to show some of the points with which you may not have been so familiar, and which may help in remembering certain facts.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and detailed so as to supply additional, pertinent information? List other studies which might supply additional, useful information. If you think you may have made errors, give reasons why you may have made them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they justified and valid as based on the available evidence? Why do you say so? RECORD additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions. How carefully did you make your observations and how many times did you repeat them?

The frog—an amphibious vertebrate animal

1. Problems

Is the frog considered to be an amphibious vertebrate because its larval, gill-bearing stages are spent in water and the adult is terrestrial and lung-bearing? Are the structures and functions of the various systems more complex than those of animals studied previously? Does a detailed study of the systems of a frog serve as a foundation for the study and understanding of comparable systems of higher vertebrates, including man? Is metamerism (segmentation) in the adult frog so modified as to form such body regions as head, thorax, and abdomen? Does the frog show such characteristics as (a) a bony endoskeleton; (b) a relatively complex, dorsal, central nervous system; (c) a special type of integument (skin); (d) a well-developed coelom; (e) an efficient muscular system; (f) pairs of jointed limbs with digits; (g) other structures and systems more highly developed than in other animals studied previously? Does the frog circulatory system consist of a three-chambered heart, arteries, capillaries, veins, and tissue spaces, which is relatively more complex and efficient than comparable systems of lower animals? Does the nervous system consist of a relatively complex dorsal brain and spinal cord, each having several pairs of nerves?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you may have concerning frogs which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From your accurate information which pertains to the problems formulate hypotheses from which you may work in their solution. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Much information can be secured about vertebrates by a detailed study of the various parts of a frog. Valuable training may be gained by making careful observations and interpretations of the various systems. Identify each structure and learn the functions of as many parts as possible.

EXTERNAL FEATURES OF FROG

Observe the shape of the body. Is there a distinct neck? Note the "hump" on the back and explain its function when the skeleton is studied. How many digits are present on each limb? Are the limbs webbed, and how far does the web extend along the digits? Examine the skin microscopically to observe any parts which are markedly glandular. Do you find any signs of scales in the skin? Open the mouth and observe that the **tongue** is attached in front and not at the back of the mouth. Note the hingelike structure of the tongue. Why is the tongue so constructed? Note the slitlike **glottis** which leads to the trachea of the respiratory system at the back of the **mouth cavity.** Note the opening to the **esophagus** which is just above the glottis.

Examine the **eyelids** and **external nares (nostrils).** The latter are located dorsally near the anterior part of the head. Pass a probe through the external nares into the mouth cavity. What is their function? Why are they so placed? Study the **tympanic membrane** on either side of the head behind the eye. Remove this membrane and observe the **tympanic cavity,** shaped like a funnel and ending below in a short **eustachian tube.** Probe the latter and note where it ends in the mouth cavity. What is its function? Does the eustachian tube in man have a similar function? Note the **anal opening** between the hind limbs.

Observe the **forelimb** consisting of **upper arm, forearm, wrist, hand,** and four functional **digits,** the **thumb** (first digit) being rudimentary. The **hind limb** consists of **thigh, shank, ankle, foot,** and five webbed **digits.** A rudimentary digit (**prehallus,** or **calcar**) is near the base of the first digit and corresponds to the thumb of the forearm.

SKELETON OF FROG

General considerations

The endoskeleton is the internal framework composed of cartilage in the embryo which becomes largely converted into bone (ossified) in the adult frog. Such bones preformed in cartilage are known as **cartilage bones.** Not all of the bones of the frog have arisen in this way, but some have appeared without passing through a cartilage stage. Such bones are known as **membrane (dermal) bones.**

Divisions of skeleton

There are two divisions of the skeleton: (1) The **axial skeleton,** which is composed of the bones of the skull, vertebral column (backbone), and sternum (breast bone) and (2) the **appendicular skeleton,** which is composed of the bones of the pectoral and pelvic girdles and the bones of the limbs attached to the girdles.

Axial skeleton

Skull. (1) The **maxillae,** or long bones, form the sides of the upper jaw. (2) The **premaxillae** are two small bones near the median line anterior to and between the maxillae. (3) The **mandible (dentary)** is the lower jaw. (4) The **vomer** is the bone in the roof of the mouth which bears the **vomerine teeth.** (5) The **cranium (brain case)** is composed of numerous bones to protect the brain. The **foramen magnum** is an opening in the posterior end of the cranium through which the spinal cord connects with the brain. Two **occipital condyles** (rounded prominences) on either side of the foramen magnum articulate with the atlas (first vertebra). Are there teeth in the upper and lower jaws? If so, where are they located and what is the arrangement?

Vertebral column. (1) The **vertebrae** are the bones which are arranged in a linear series to form a segmented axis. (2) The **atlas** is the first vertebra (what is its function? how does its structure differ from other vertebrae?). (3) The **sacrum** is the last vertebra (what bones are attached to it?). (4) The **urostyle** is a bladelike bone at the posterior end of the vertebral column (what is its relation to the "hump" in the back? what is its function?).

DETAILED STUDY OF VERTEBRA. (1) The **centrum** is the ventral cylindrical portion. (2) The **neural arch** is dorsal to the centrum, and has a **spinal canal** through which the spinal cord passes. (3) The **neural (dorsal) spine** is the dorsal projection of the neural arch. (4) The **transverse process** is the lateral projection on each side of the vertebra.

Label the DRAWING of a vertebra (end view).

Appendicular skeleton

Pectoral girdle. The bones of this girdle nearly encircle the anterior part of the body and form a basis for the attachment of the bones of the forelimbs. (1) The **sternum** ("breast bone") is actually a number of bones on the ventral side and is classified with the axial skeleton. (2) The **clavicle**

is the lighter and more anterior bone of the two which extend from the sternum to the shoulder region. (3) The **coracoid** is the heavier and more posterior bone of the girdle. There are right and left clavicles and right and left coracoid bones. (4) The **scapula is a broad, flat bone located ventrodorsally** and has a cartilaginous **suprascapula** located dorsally. What functions can be performed by muscles which are attached to these bones? The forelimb articulates with the socket called the **glenoid fossa.**

Study and label the DRAWING of the pectoral girdle.

Foreleg. (1) The **humerus** is a bone in the proximal part of the forelimb and articulates with the **glenoid fossa.** (2) The **radioulna** is a single, fused bone distal to the humerus. Why does it have such a name? (3) **Carpals** are two rows of bones which form the wrist. Compare this construction with that of man. (4) **Metacarpals** are four bones distal to the carpals and form the "hand." (5) **Phalanges** are bones which form the digits. How many phalanges in each digit? Compare this with man.

Study and label the DRAWING of the foreleg.

Pelvic girdle. This girdle, like the pectoral girdle, is formed by a right and left side which meet to form an arch. This girdle articulates with the sacral vertebra, whereas at its posterior end at either side is the **acetabulum,** or socket for articulation with the femur of the hind leg. Observe that three bones (the **ilium, ischium,** and **pubis**) meet to form the acetabulum. Observe the bladelike **urostyle** extending posteriorly from the sacral vertebra. What is its function? Note that the ilium is long and extends anteriorly from the acetabulum; the ischium is located dorsally, whereas the pubis is located ventrally.

Study and label the DRAWING of the pelvic girdle.

Hind leg. (1) The **femur** is a single bone of the proximal part of the hind limb and articulates with the acetabulum. (2) The **tibiofibula** is a fused bone distal to the femur. (3) **Tarsals** are two rows of bones which form the "ankle." The proximal row consists of two long bones, the **astragalus** and the **calcaneum.** The bones of the distal row are not easily observed in prepared skeletons. The calcaneum corresponds to the "heel bone." (4) **Metatarsals** are five bones distal to the tarsals. (5) **Phalanges** are bones which form the digits (toes). How many bones in each digit? Compare this with man. (6) **Prehallux** (calcar) is the rudimentary digit at the inner side of the first digit.

Study and label the DRAWING of the hind leg.

General questions on skeleton

List the various functions of a skeleton. What constitutes a joint? Joints may be classified as follows.

Synarthroses. Synarthroses are immovable joints.

Amphiarthroses. These are slightly movable joints.

Diarthroses. Diarthroses are freely movable joints.

GLIDING JOINTS. These are joints in which the articular surfaces permit a gliding movement.

HINGE JOINTS. Hinge joints permit movements to and fro in one plane, like a hinge.

BALL-AND-SOCKET JOINTS. These are joints in which a rounded head articulates with a cuplike cavity.

Give as many examples as possible for each type of joint from your study of the frog skeleton. Each joint of a skeleton can be classified somewhere among the various types. Give the function of each type of joint listed.

MUSCLES OF FROG (VENTRAL VIEW)

Remove carefully the skin from the entire body in order to study the superficial muscles. Not all muscles of the frog will be studied, but a few of the superficial ones will illustrate the construction and functions of them. In describing muscles the following terms are applied. **Origin**—the end which remains fixed during contraction. **Insertion**—the movable end. **Flexion**—the bending of a joint. **Extension**—the straightening of a joint. **Abduction**—the drawing of a part away from the median line. **Adduction**—the drawing of

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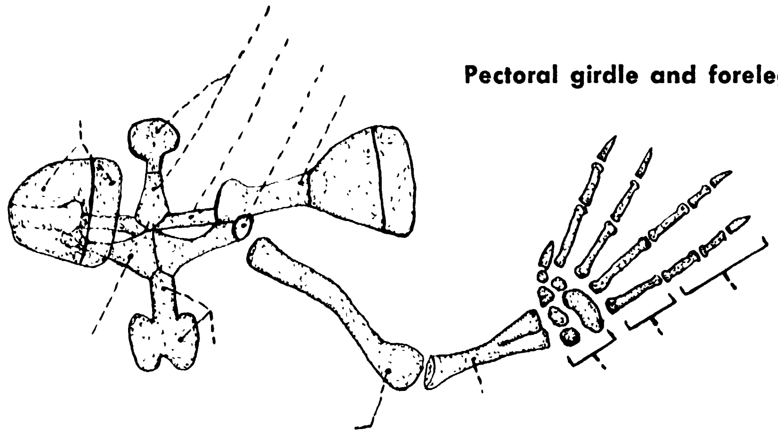
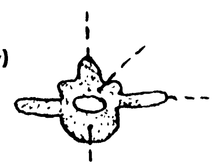
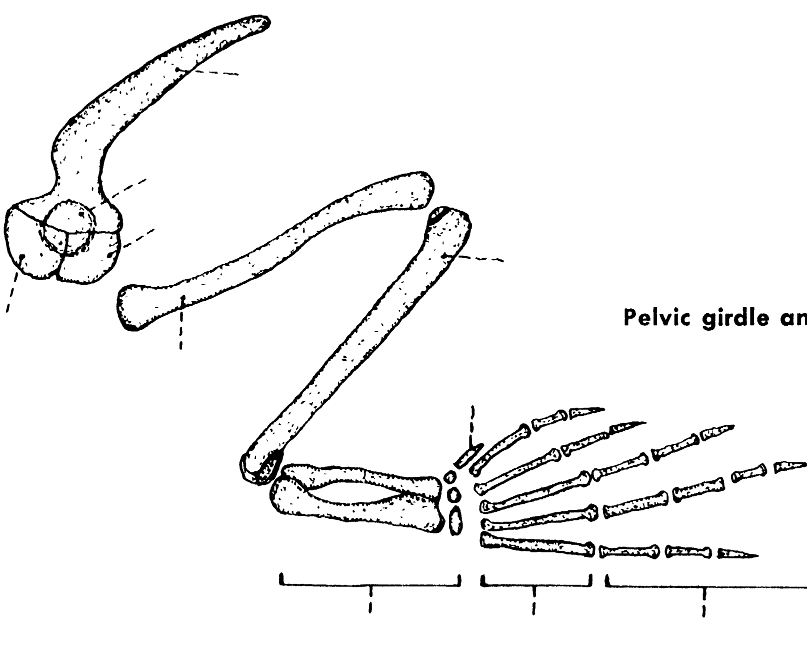
Pectoral girdle and foreleg



Vertebra (end view)





Pelvic girdle and hindleg

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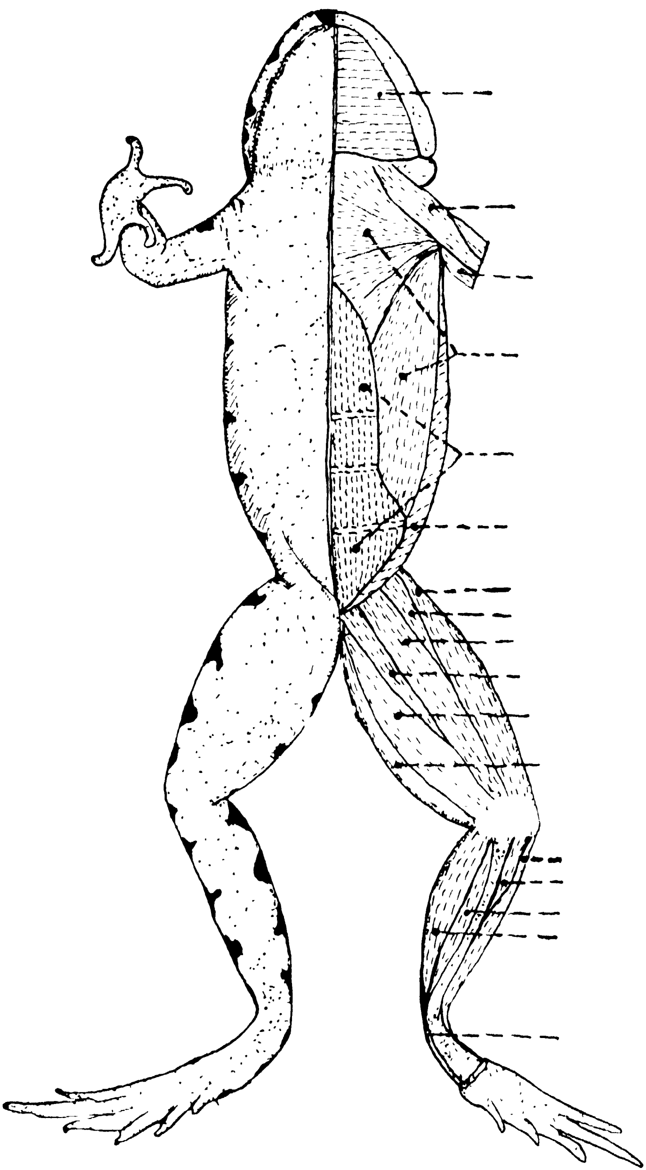

Muscles of the frog (ventral view)

a part toward the median line. What functions do such muscles as flexors, extensors, abductors, adductors, etc., perform?

Superficial muscles of head, trunk, and forelimb (ventral view)

Study each of the following muscles, carefully observing all the details.

Mylohyoid (submaxillaris). This muscle stretches across the ventral side of the throat from one side of the mandible (lower jaw) to the other. It raises the floor of the mouth in breathing and swallowing.

Deltoideus. This is a triangular muscle which has its origin on the scapula, clavicle, and sternum. It is inserted on the humerus. It draws the forelimb forward and extends it.

Triceps brachii (anconeus). There are three points of origin (three heads) on this muscle, one on the scapula and two on the humerus. It is inserted on the forearm and it extends (straightens) the arm.

Pectoralis. This large, fan-shaped muscle is composed of a **sternal portion** and an **abdominal portion.** Origin is on the sternum and fascia (bandlike connective tissue) of the abdominal wall. Insertion is on the humerus. Its functions are to flex, adduct, and rotate the arm. The sternal portion is divided into three parts.

Rectus abdominis. This is a longitudinal muscle along the midventral line with transverse bands to give it a segmented appearance. The linea alba (white line) separates the right and left rectus abdominis muscles. Origin is in the pelvic region. Insertion is on the sternum. Its functions are to support the abdominal viscera (internal organs) and to depress the sternum.

External oblique. This sheetlike muscle is on the lateral-ventral side of the abdomen, with fibers running obliquely. Origin is in the dorsal fascia of the vertebrae and on the ilium. Insertion is on the sternum and linea alba in the midventral region. It functions to support the viscera and constrict the abdomen.

Label the DRAWING of the muscles described, after having identified each one on the frog.

Superficial muscles of the hind limb (ventral view)

Study each of the following muscles of the thigh and shank, carefully observing all the details.

Thigh

The superficial muscles of the thigh consist of triceps femoris, adductor longus, sartorius, adductor magnus, gracilis major, and gracilis minor.

Triceps femoris. This is a large muscle on the anterior and dorsal sides of the thigh. Three divisions of this muscle are (1) **vastus internus** on the anterior-ventral side; (2) **vastus externus** on the dorsal side; and (3) **rectus anticus femoris** which inserts on the other two. Origin is on the acetabulum and ilium bone of the pelvis. Insertion is on the proximal end of the tibiofibula. It flexes (draws up) the thigh and extends (straightens) the shank.

Adductor longus. Much of this thin, flat muscle is concealed by the sartorius. Origin is on the ilium. Insertion is on the femur. It functions to adduct the thigh.

Sartorius. Sartorius is a ribbonlike muscle on the midventral surface of the thigh. Origin is on the ilium. Insertion is on the proximal end of the tibiofibula. It functions to flex, adduct, and rotate the thigh and flex (bend) the shank.

Adductor magnus. Only a triangular portion of this muscle may be visible unless the sartorius is raised. Origin is in the pubic region. Insertion is on the distal end of the femur. Its function is to adduct the thigh and leg.

Gracilis major (rectus internus major). Gracilis major is a large muscle anterior to the gracilis minor and partly conceals the adductor magnus. Origin is on the ischium bone of the pelvis. Insertion is on the proximal end of the tibiofibula. It functions to extend the thigh and flex the knee joint.

Gracilis minor (rectus internus minor). This is a thin, ribbon-shaped muscle on the posterior border of the thigh. Origin is on the ischium bone. Insertion is on the proximal end of the tibiofibula. It functions to extend the thigh and flex the knee joint.

Shank

Muscles of the shank include extensor cruris, tibialis anticus, tibialis posticus, and gastrocnemius.

Extensor cruris. This is a wedge-shaped muscle on the anterior-ventral side of the shank. Origin is on the distal end of the femur. Insertion is on the anterior part of the tibiofibula. It extends the foot.

Tibialis anticus. This thin muscle covers the anterior part of the tibiofibula. Origin is on the distal end of the femur. Insertion is on the ankle (astragalus and calcaneum bones). It functions to flex the ankle and extend the foot.

Tibialis posticus. This muscle is posterior to the tibiofibula and anterior to the gastrocnemius muscle. Origin is on the posterior part of the femur. Insertion is on the ankle (astragalus bone). It functions to flex and extend the foot.

Gastrocnemius. This large muscle forms the "calf of the leg." Origin is on the distal end of the femur. Insertion is by means of the **tendon of Achilles** on the sole of the foot. It functions to flex the knee, extend the foot, and flex the toes.

Label the DRAWING of the muscles described after having identified each one on the frog.

Remove the ventral, abdominal wall in the following manner. Make a longitudinal incision slightly to one side of the midventral line, beginning at the posterior part of the abdomen and cutting forward through the pectoral girdle to the throat region. Dissect carefully so that internal organs are not injured, particularly the abdominal vein which is attached beneath the abdominal wall in the midventral region. Take care in cutting the pectoral girdle so that structures beneath it are not injured. Make transverse incisions just in front of the hind leg and just posterior to the pectoral muscles, cutting laterally. After freeing the abdominal vein so that it remains with the viscera, pin the frog and the two flaps of the body wall in a waxed dissecting pan. The appearance of the viscera after the removal of the body wall will depend on the sex. If the frog is a female full of black eggs the viscera may be displaced anteriorly, and the eggs must be removed with great care before the abdominal structures can be seen.

CIRCULATORY SYSTEM

Heart. The heart is located in the anterior part of the body cavity, ventral to the liver, Carefully remove the membranous **pericardium** which surrounds the heart. Observe the cone-shaped, muscular **ventricle** with its apex pointing posteriorly. Identify the thin-walled **right** and **left auricles (atria)** anterior to the ventricle. Note the tubular **conus (truncus) arteriosus** which extends anteriorly from the ventricle and which divides into **right** and **left aortic arches.** Each aortic arch gives rise to an anterior **carotid arch** (common carotid) with arteries leading to the head and tongue, a **systemic arch,** and a posterior **pulmocutaneous arch** with arteries leading to the lung and skin. The right and left systemic arches unite to form the **dorsal aorta** (ventral to the spinal column) from which arteries lead to various parts of the body and hind legs.

Arterial system. Study the arterial system in a fresh specimen, or one whose circulatory system has been injected with a colored material. Attempt to identify as many arteries as possible.

Make a DRAWING of the arterial system with all parts labeled correctly.

Venous system. Turn the ventricle upward and observe the dark, thin-walled **sinus venosus** which empties blood into the **right auricle. Right** and **left anterior venae cavae (precavals)** return blood to the anterior part of the sinus venosus from the right and left sides of the anterior part of the body. A **posterior vena cava (postcaval)** returns blood to the sinus venosus from the posterior part of the body.

The **pulmonary veins** return blood from the right and left lungs to the **left auricle.** The **abdominal vein,** located in the midventral line, arises posteriorly from two **pelvic veins** (from hind legs) and passes anteriorly, sending branches to the liver and also continuing into the right auricle. The abdominal vein also receives the **hepatic portal vein** which carries blood from the stomach, intestine, and spleen. Blood from the hind legs and posterior parts of the body may be carried to the kidneys through the **renal portal veins.** From the kidneys the blood passes through the **renal veins** into the posterior vena cava. For the location of additional veins and arteries reference should be made to charts, models, or illustrations in the text. Thus the circulatory system may be divided into a **pulmonary portion** (through the lungs and skin) and a **systemic portion** (through the remainder of the body).

DRAW the venous system, labeling all parts correctly. Add as many blood vessels as possible from your study of the dissected frog.

DIGESTIVE SYSTEM

The ***mouth*** (oral cavity) has been studied previously. Study the location, structure, and functions of the following.

1. A short ***esophagus*** leads from the mouth to the stomach.

2. A ***stomach,*** a somewhat cylindrical organ, is marked off from the small intestine by a constriction, the **pyloric valve (pyloris).** The end which joins the esophagus is called the **cardiac end.** Why is it so called?

3. The ***duodenum*** is that part of the small intestine which follows the stomach immediately. The **bile ducts** from the liver and the **pancreatic duct** from the pancreas enter the duodenum.

4. The ***ileum*** is a much-coiled part of the small intestine leading from the duodenum to the large intestine.

5. The ***large intestine*** (**rectum**) proceeds backward until the entrance from the urinary bladder is reached.

6. The ***cloaca*** is an enlarged structure extending from the large intestine to the **anus.** The cloaca receives tubes from the urinogenital system (excretory and reproductive systems) and from the urinary bladder.

7. The ***anus*** opens to the exterior between the hindlegs.

8. The ***liver*** is a large, dark-colored, three-lobed organ, two lobes of which are on the left side and one on the right. The **gallbladder** is a small sac under the right lobe of the liver. It may be distended or collapsed and is usually stained green. The bile secreted by the liver is stored in the gallbladder. **Bile ducts** connect the liver with the gallbladder and the latter with the duodenum. Attempt to trace them.

9. The ***pancreas*** is an irregular, branched mass of tissue lying in the curvature between the stomach and duodenum. It is slightly thicker and different in color than the mesenteries (membranous tissues) which attach it to the intestine.

10. The ***fat bodies*** are irregular, branched, yellowish bodies, one lying anterior to the stomach on the left side and the other anterior to the intestine on the right. Fat bodies store foods for use particularly when the frog hibernates.

11. The ***mesenteries*** are thin membranes which connect the digestive organs to each other and to the dorsal wall of the abdomen. Note the blood vessels which are associated with the mesenteries.

In the mesentery which holds the ileum to the dorsal wall is a dark, reddish, oval body, the **spleen.** In a female with eggs the position of the spleen may be somewhat changed.

DRAW the digestive system with all parts labeled, after identifying each part.

RESPIRATORY SYSTEM

Study this system carefully, observing the following.

1. The ***glottis*** is a slitlike opening at the back of the mouth (oral cavity) which leads to the larynx (voice box). What is the function of the glottis?

2. The ***cartilaginous larynx*** is a rudimentary organ which leads to the trachea and has two elastic, bandlike **vocal cords** for sound production.

3. The ***trachea*** is a short tube which divides into two **bronchi,** one bronchus for each lung.

4. The ***lungs*** are two thin-walled, dark-colored organs, one lying on either side of the median line under the anterior portion of the liver on a level with the heart. They can be seen by raising the liver and may be large or small depending on their air content.

5. The ***skin,*** although not connected directly with the lungs, also plays an important role in respiration. Study the structure of the skin microscopically to see how it might perform such a function.

EXCRETORY SYSTEM

Study the parts of this system, noting particularly the following.

1. The ***kidneys*** are located near the median line in the dorsal, posterior region of the abdominal cavity. The pair of kidneys are dark-colored, elongated, and flattened. They lie beneath the **peritoneum** or membrane which lines the abdominal cavity. Blood vessels (renal arteries and veins) enter and leave the kidneys on their medial surface.

2. A pair of ***ureters*** (**wolffian ducts**) lead from the lateral posterior part of each kidney to the cloaca. The ureters are thin and light, whereas the renal portal veins nearby are dark.

3. The ***urinary bladder*** is a thin-walled, bilobed sac which connects with the cloaca and stores liquid wastes until they are voided.

Complete the DRAWING of the excretory system, labeling all parts.

REPRODUCTIVE SYSTEM

Study the male and female reproductive systems in two different frogs, noting the following.

1. ***In the female*** the paired **ovaries** are saclike organs near the **kidneys** and bear **eggs** of various sizes. When large and filled with eggs the ovaries may fill a large portion of the abdominal cavity. After the eggs are laid the ovaries are smaller and occupy relatively the same position as the testes in the male.

In the female the paired **oviducts** (**müllerian ducts**) are thick, white, coiled tubes, one on each side of the abdominal cavity. The anterior end of each has a funnel-shaped **ostium** (opening) through which eggs enter from the abdominal cavity. The posterior end of each oviduct is enlarged to form a **uterus** (**egg sac**) which connects with the **cloaca.**

2. ***In the male*** the paired **testes** are ovoid, white organs lying in the middle of the abdominal cavity and connected with the kidneys by means of small, tubelike **vasa efferentia.** The **sperms** pass through these into a duct in the kidney known as **Bidder's canal,** which conducts them to the **ureters** (**wolffian ducts**). These **ureters** (also called **vasa deferentia**) serve as a **sperm duct** and as a urinary duct. Posteriorly each wolffian duct has an enlargement, the **seminal vesicle,** for the temporary storage of sperms. The seminal vesicles are connected with the **cloaca.** A pair of **rudimentary oviducts** may be observed in the male frog.

Identify all parts and complete the DRAWINGS of both male and female reproductive systems, labeled correctly.

COORDINATION (NERVOUS SYSTEM AND ENDOCRINE GLANDS)

Coordination of the many activities of a frog is accomplished by the nervous system and by the hormones produced by the endocrine (ductless) glands.

Brain

Expose the brain by breaking away small pieces of the bony roof of the cranium with a heavy forceps. Take care that the soft brain is not injured. Beginning at the anterior end and observing posteriorly, the following parts of the brain are to be noted from a dorsal view.

1. A pair of small ***olfactory lobes*** are closely attached to the cerebral hemispheres and possess **olfactory** nerves which lead to the nostrils for a sense of smell.

2. A pair of elongated ***cerebral hemispheres*** (**cerebrum**) are closely united along their median line.

3. The ***diencephalon*** (**thalamus**) appears as a depression between the cerebral hemispheres and the optic lobes. The **pineal body** (**epiphysis**) is a small body on the dorsal surface of the diencephalon of the brain.

4. A pair of prominent, ovoid ***optic lobes*** posterior to the diencephalon and resting on the midbrain are associated with the sense of sight.

5. A ***cerebellum*** is just posterior to the optic lobes and appears as a transverse ridge just anterior to a depression.

6. The ***medulla oblongata*** attaches the brain to the spinal cord and contains a depression below which is the **fourth ventricle** of the brain. Pairs of **cranial nerves** originate from various parts of the brain.

Text continued on p. 177.

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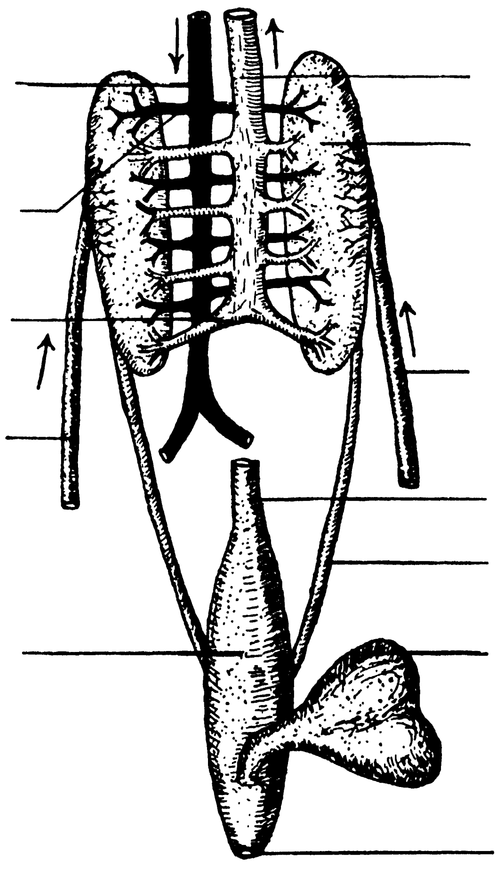

Frog excretory system

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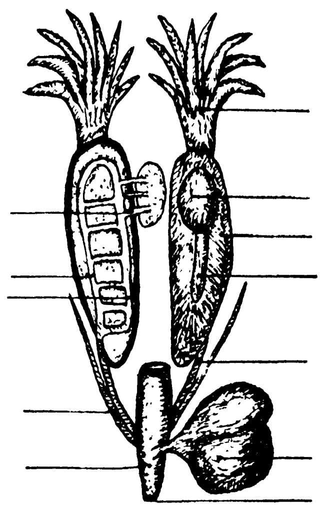
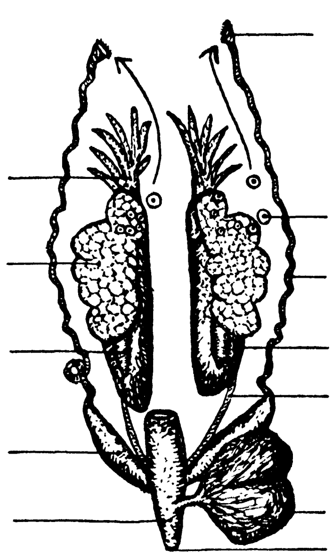


Frog reproductive system (male)



Frog reproductive system (female)

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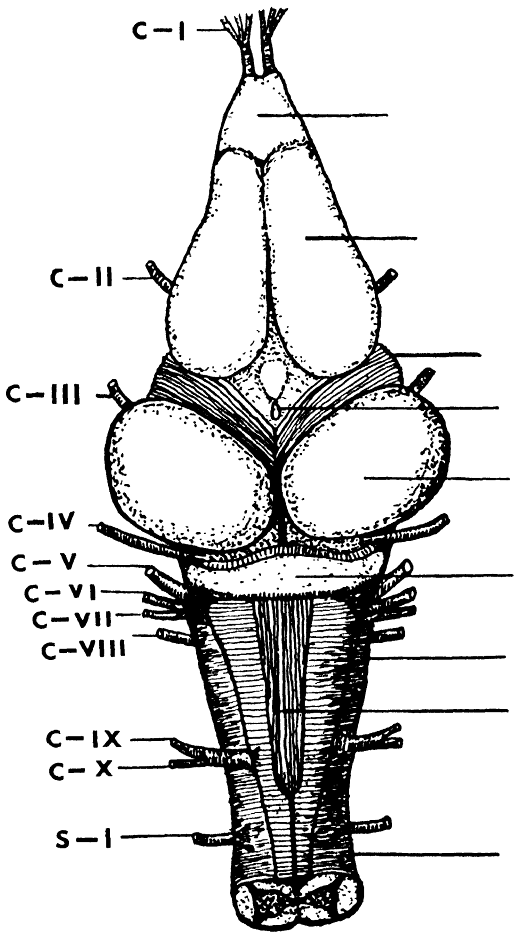

Frog brain (dorsal view)

Spinal cord and spinal nerves

Remove all viscera from the abdominal cavity, noting the ten pairs of whitish **spinal nerves** originating from the **spinal cord** within the vertebral column.

DRAW the spinal cord and spinal nerves with all labeled accurately.

Endocrine glands

A summary of the endocrine (ductless) glands for man is given in the chapter, The Biology of Man.* The following are some of the endocrine glands of the frog.

1. An ***adrenal gland*** on the ventral surface of each kidney produces a hormone, **adrenaline** (**epinephrine**) for increasing blood pressure and contracting pigment cells.
2. The ***pancreas,*** near the stomach, has specialized groups of cells called the **islets of Langerhans** which secrete the hormone **insulin** possibly to regulate sugar metabolism.
3. The ***thyroid glands,*** on either side of the hyoid apparatus in the floor of the mouth, secrete hormones associated with the metamorphosis of the frog.
4. The ***pituitary*** (**hypophysis**) is a trilobed gland located at the base of the brain (ventral side). Its various hormones stimulate growth, influence the release of sperms and eggs, influence chromatophores of the skin, regulate the water intake of the skin, etc.
5. The ***pineal body*** is a gland on the dorsal side of the diencephalon of the brain.
6. The hormones of the ***gonads*** (**sex organs**) regulate the actions of the sex glands in their cycles and influence the secondary sexual traits.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Did you make your studies with sufficient accuracy to supply additional, pertinent information? If you think that you made errors, give reasons why you made them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they justified and valid as based on the available information? RECORD additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions. How carefully did you make your observations and how often did you repeat them? Did you actually see all the things described, or did you "guess" at certain ones? Is the latter attitude really scientific?

*Beaver: General Biology.

The pig—a mammalian vertebrate animal

1. Problems

Is the pig considered to be a mammalian vertebrate animal because of mammary glands and a vertebral column? Are the structures and functions more complex than in Amphibia (such as the frog) yet comparable to those of other mammals such as man? Does a study of the systems of a pig give a good basis for understanding comparable systems in man? Are there any systems in the pig that are not common in lower animals? Are there certain systems of the pig which are improvements over similar systems in lower animals? Do mammals have several methods of eliminating wastes? Are there improvements in the construction of a four-chambered heart (as in birds and mammals) over the heart of amphibians (as in the frog)? Are there improvements in the structure and functions of a mammalian nervous system over lower forms? Are the endocrine (ductless) glands of a pig similar to those of man, structurally and functionally?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you have concerning mammals in general and the pig specifically.

3. Formulation of hypotheses and determination of methods of investigation

From your pertinent information formulate hypotheses from which you may work toward the solution of the problems. RECORD methods of investigation which will supply additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Much pertinent information concerning mammalian vertebrates can be secured by a study of a pig. Valuable training in observation and interpretation may be gained through a careful dissection and study of the various structures and systems, including the functions of as many parts as possible.

EXTERNAL FEATURES OF PIG

Observe that the animal is divided into **head, neck, trunk,** and **tail.** How does this differ from man? Note the **umbilical cord** arising from the midventral part of the abdomen, through which the fetal pig received its nourishment before birth. Observe the pair of **ears (pinnae)** and the pair of **eyes.** The latter possess **upper** and **lower lids** and a **third eyelid (nictitating membrane)** in the inner corner of each eye. A pair of **nostrils (external nares)** are present on the tip of the nose. Why is sensory equipment placed at the anterior end of an animal?

Observe the **forelimbs** and **hind limbs** with their terminal **digits,** noting that the first digit is absent and the second and fifth are reduced in size. Note that a pig walks on the tips of its toes (**digital locomotion**). How does this compare with man? Observe the sex of the fetal pig. If a male there are two saclike structures, the **scrotal sacs** containing **testes**, at the posterior end of the body. A **urogenital opening** is just posterior to the umbilical cord. Observe the muscular **penis** just beneath the skin between the hind limbs and passing forward toward the urogenital opening. If a female the **urogenital opening** is just ventral to the anal opening, beneath the tail. Two rows of **mammary glands** are located beneath the skin of the abdomen. How many glands in each row, and does this number affect the number of offspring which can be suckled at one time?

DRAW such structures and systems as suggested by the instructor, labeling all parts correctly.

SKELETON

Some parts of the skeleton of a fetal pig may still be cartilaginous and soft, depending on the age of the fetus. Since complete ossification has not taken place, possibly the study of a skeleton of some other mammal, such as a cat or man, may be desirable, and the pig skeleton may be used for comparison.

The skeleton may be classified into (1) **axial skeleton** composed of **skull, vertebral column, ribs,** and **sternum (breast bone)**, and (2) **appendicular skeleton** composed of **pectoral girdle** and its **forelimbs,** and **pelvic girdle** and its **hind limbs.**

In the pig **skull** the bones of the **cranium (brain case)** are elongated and the **mandible (lower jaw)** is large in contrast to those in man. The bones of the **cranial part of the pig skull** have the same names as in man, although their shapes may be different. The **facial part of the pig skull** consists of 19 bones, whereas there are only 14 in man, and the pig facial bones are elongated relatively.

The **vertebral column** of the pig, cat, and man is contrasted in Table 2.

There are 14 or 15 pairs of **ribs** in the pig; the first 7 pairs join the sternum and the fifteenth pair consists mostly of cartilage. In the cat there are 13 pairs of ribs. In man there are 12 pairs of ribs, the first 7 pairs ("true" ribs) articulating with the thoracic vertebrae by means of cartilage; the next 3 pairs ("false" ribs) do not possess costal cartilage for attachment to the sternum (breast bone); and the last 2 pairs ("floating" ribs) have no attachment to the sternum.

The **pectoral girdle** of the fetal pig consists of a pair of cartilaginous, blade-shaped **scapulae (shoulder blades)**, whereas in the cat and man there is an additional pair

Table 2. Comparison of vertebral column of pig, cat, and man

	Cervical (neck)	*Thoracic (chest)*	*Lumbar (lower trunk)*	*Sacral*	*Coccygeal or caudal (tail)*
Pig	7	14 to 15	6 to 7	4	23
Cat	7	13	7	3*	22 to 23
Man	7	12	5	5*	3 to 5*

*Bones more or less fused.

Table 3. Comparison of forelimb in pig, cat, and man

Pig	Humerus	Radius	Ulna	8 carpal bones	4 metacarpal bones	12 phalanges in 4 digits
Cat	Humerus	Radius	Ulna	7 carpal bones	5 metacarpal bones	14 phalanges in 5 digits
Man	Humerus	Radius	Ulna	8 carpal bones	5 metacarpal bones	14 phalanges in 5 digits
				(wrist)	(hand)	

Table 4. Comparison of hind limb in pig, cat, and man

Pig	Femur	Tibia	Fibula	Patella	7 tarsal bones	4 metatarsal bones	12 phalanges in 4 digits
Cat	Femur	Tibia	Fibula	Patella	7 tarsal bones	5 metatarsal bones	12 phalanges in 4 digits
Man	Femur	Tibia	Fibula	Patella	7 tarsal bones	5 metatarsal bones	14 phalanges in 5 digits
				(knee cap)	(ankle and heel)	(instep)	

of **clavicles (collar bones)**. A comparison of the forelimb in the pig, cat, and man is shown in Table 3.

The **pelvic girdle** of the pig consists of the **ilium, ischium,** and **pubis bones,** which are unfused, whereas in man the three are fused. A comparison of the hind limb in the pig, cat, and man is shown in Table 4.

MUSCULAR SYSTEM

The muscles of a fetal pig may not be fully developed and are easily damaged. In dissecting and observing a muscle be certain to ascertain its exact **location,** its **origin** (least movable end of attachment), its **insertion** (movable end when the muscle contracts), and its **functions.** The thicker, middle part of a muscle is called its **belly.**

Place the pig (ventral side up) in a dissecting pan and cut through the skin only, **starting** at the base of the neck. Continue **the cut** (midventral incision) posteriorly **to the** level of the hind limbs, being careful to cut around the umbilical cord so as **not** to damage it. Make a cut down the medial surface of the hind limbs to the hoof. Make a similar cut down the forelimbs to the hoof. Fold back the skin from the body and appendages. With the back of the scalpel carefully remove the gelatinous material which covers the muscles. **Fasciae** (L. *fascia,* bandage), singular *fascia,* are fibrous membranes which enclose muscles to hold them intact. Muscles may be studied more easily if they are partially dried. A few muscles have been selected to show differences and similarities between pig and man, as shown in Table 5.

Table 5. Comparison of muscles in pig and man

Muscle	*Pig*	***Man***
A. Shoulder and back		
1. Latissimus dorsi (L. *latus,* side; *dorsum,* back)	Broad muscle extending downward and anteriorly around sides of thoracic region Origin: thoracic and lumbar vertebrae Insertion: proximal (near) end of humerus Function: moves forelimb posteriorly	Large, fan-shaped muscle of dorsal and lateral sides of thorax and abdomen Origin: thoracic, lumbar, and sacral vertebrae, and lower ribs Insertion: humerus Functions: draws arm backward and rotates it inward
B. Chest and abdomen		
1. Pectoralis major (L. *pectus,* breast; *major,* great)	Fan-shaped muscle on ventral and lateral part of thorax Origin: sternum Insertion: proximal end of humerus Function: draws forelimb toward chest	Large fan-shaped muscle on the ventral part of the thorax Origin: clavicle, sternum, and true ribs Insertion: humerus Functions: draws arm downward to side of chest or across chest; also rotates arm inwardly
2. External oblique (L. *externus,* outside; *obliquus,* slanting)	Muscle fibers extend downward and backward to form lateral part of abdominal wall Origin: lower ribs Insertion: linea alba (white line) in midventral abdomen Function: constricts abdomen	Strong, superficial muscle of front and side walls of abdomen Origin: lower eight ribs Insertion: iliac bone and linea alba (white line) in midventral abdomen Function: controls size of abdomen
C. Upper forelimb		
1. Triceps brachii (L. *tres,* three; *caput,* head); (*brachium,* arm)	Large muscle covering much of outer surface of upper part of forelimb, and divided into 3 parts Origin: humerus Insertion: ulna Function: extends forelimb	Muscle on back of upper arm and arising by 3 heads Origin: scapula and humerus Insertion: ulna Function: extends forearm (antagonist of biceps)

Table 5—cont'd

Muscle	*Pig*	*Man*
C. Upper forelimb—cont'd		
2. Biceps brachii (L. *bis,* two; *caput,* head); (*brachium,* arm)	Small, spindle-shaped muscle along anterior surface of humerus (somewhat covered by another muscle) Origin: scapula (shoulder blade) Insertion: radius Function: flexes (bends) forelimb	Large muscle on front of upper arm and arising by 2 heads Origin: scapula (shoulder blade) Insertion: radius Function: flexes (bends) forearm; (antagonist of triceps)
D. Upper hind limb (thigh)		
1. Gluteus maximus (Gr. *gloutos,* buttock; L. *maxima,* great)	Broad, thin muscle near anterior surface of upper hind limb Origin: sacral and caudal vertebrae Insertion: tensor fascia lata (large triangular muscle inserted on patella or kneecap) Function: abducts thigh	Large muscle which helps to form buttock Origin: ilium, sacrum, and coccyx bones Insertion: femur Functions: extends and adducts femur
E. Lower hind limb (shank)		
1. Gastrocnemius (Gr. *gaster,* belly; *kneme,* tibia)	Large muscle forming "calf" of hind limb Origin: femur (lower end) Insertion: calcaneum (metatarsal bone) by means of tendon of Achilles Function: extends foot	Large muscle which helps to form "calf" of leg Origin: femur Insertion: calcaneum bone (heel bone) by means of long tendon of Achilles Functions: extends foot at ankle joint; flexes femur upon tibia

DIGESTIVE SYSTEM

Place the pig (ventral side up) in a dissecting pan and spread the limbs, tying them with string. **Dissect with great care** and make a midventral incision starting at the base of the neck, continuing posteriorly to the umbilical cord. If the pig is a female, continue the incision around both sides of the cord and continue the midventral incision back to the anus. If the pig is a male, proceed as with the female down to the cord, then make two incisions posteriorly toward the hind limbs, avoiding damage to the penis which lies in the midventral line.

For both sexes continue the incision until the body cavity (coelom) is exposed. Just posterior to the forelimbs and just anterior to the hind limbs cut through the body wall so that it can be pinned down. Free the muscular **diaphragm** (between the thorax and abdomen) from the body wall. Note the dark, tubelike **umbilical vein** extending from the cord forward to the liver. Tie a string around the vein in two places and cut the vein between the two strings, permitting the cord to be pulled back.

Remove the skin from the face and carefully cut through the angle of the jaws to permit examination of the **oral cavity.** In the oral cavity observe the muscular **tongue** and rows of **teeth,** if they have erupted in a fetus of this age. Observe 3 pairs of **salivary glands** as follows: (1) **parotid** glands at the side of the face near the posterior angle of the jaw; (2) the oval, reddish **submaxillary** glands just ventral to the parotid; (3) **sublingual** glands beneath the tongue. Each gland has a duct which leads into the oral cavity into which the digestive juices are secreted.

In dissecting and observing in the neck region **be careful not to destroy** the large, bilobed thymus gland which also extends into the thoracic cavity. Also be careful not to destroy the smaller thyroid gland near the median line.

The posterior continuation of the oral cavity is the **pharynx** which serves both digestive and respiratory systems. At the posterior part of the pharynx note the **esophageal opening** leading to the soft, muscular **esophagus** just dorsal to the trachea (windpipe). The esophagus leads through the muscular diaphragm into the **stomach.** The latter consists of a **cardiac end** (nearest the heart, or cardium) and a **pyloric end,** which contains a **pyloric valve** leading into the small intestine. Make an incision in the stomach wall, observing the **internal folds.**

The first part of the **small intestine** is the **duodenum.** The next two regions of the small intestine are the **jejunum** and **ileum,** which are difficult to differentiate. Remove a segment of the intestine, open it lengthwise, and examine it under water. Observe the numerous fingerlike **villi,** well supplied with blood vessels, which increase the absorbing ability of the small intestine.

The first part of the **large intestine** is the **colon** which leads to the **rectum.** The ileum enters the colon in such a way that it forms a tubelike **cecum.** The last part of the large intestine is the straight **rectum** which terminates at the **anus.** In order to observe structures better it may be desirable to cut through the cartilage of the pelvic girdle. **Be careful not to destroy structures** in this area, especially if the fetus is a male.

The **digestive glands** include the salivary glands, liver, intestinal glands, and pancreas. (1) The **salivary glands** were considered previously. (2) A large, brownish **liver** is composed of **four main lobes** and is located at the anterior end of the abdominal cavity, just posterior to the diaphragm. The liver secretes **bile** which is stored in a green, saclike **gallbladder** located between the lobes of the liver on the right side. A **cystic duct** from the gallbladder and a **hepatic duct** from the liver unite to form a **common bile duct** which empties into the duodenum. (3) **Intestinal glands** are scattered among the villi of the small intestine. (4) An elongated **pancreas** lies between the stomach and duodenum and its extremely small **pancreatic duct** carries pancreatic juice to the duodenum.

CIRCULATORY SYSTEM

In order to observe parts of the circulatory system certain other structures may have to be removed and dissected carefully. If the thymus gland has not been removed previously, do so by carefully picking away this tissue with your forceps (not a scalpel). In the process be careful not to destroy the reddish, beanlike thyroid gland at the base of the neck.

The circulatory vessels are divided into **arteries** which carry blood away from the heart and **veins** which carry blood toward the heart. Extremely small **capillaries** connect arteries and veins. The **arterial system** is divided into (1) **systemic** (going to the body) and (2) **pulmonary** (going to the lungs).

Heart

If dissection has been done properly the **heart,** surrounded by a membranous, saclike **pericardium,** will be observed in the thoracic cavity anterior to the diaphragm and between the two lungs. Slit the pericardium to expose the heart. To assist in the study of the pig heart it may be helpful to study a heart of such mammals as the cat, beef, or man, or at least models and charts which show the heart, blood vessels, etc.

A ventral view of the heart shows muscular **right** and **left ventricles** toward the apex (tip) and **right** and **left auricles** toward the anterior-lateral regions of the heart. They may appear as collapsed, thin-walled, saclike structures. (The rights and lefts refer to the animal's right and left.) In the depression between the ventricles observe the **coronary arteries** and **veins** which carry blood to and from the heart muscles. They are in the form of a corona (crown).

Using either the heart of your pig or a fresh beef or pig heart, locate the right and left auricles and right and left ventricles. With a sharp scalpel carefully cut the walls of the ventricles and auricles, noting carefully the differences in their thickness. Identify the following: (1) **tricuspid valve** (right auriculoventricular valve) between the right auricle and right ventricle; (2) **bicuspid valve** (left auriculoventricular valve) between the left auricle and left ventricle; (3) **semilunar valves,** which can be seen best by looking into the aorta or pulmonary artery. After they have been located cut the side of the pulmonary artery and slip your finger in the valve to stretch it. These three semilunar valves combine to prevent blood from rushing back into the ventricles; (4) **Chordae**

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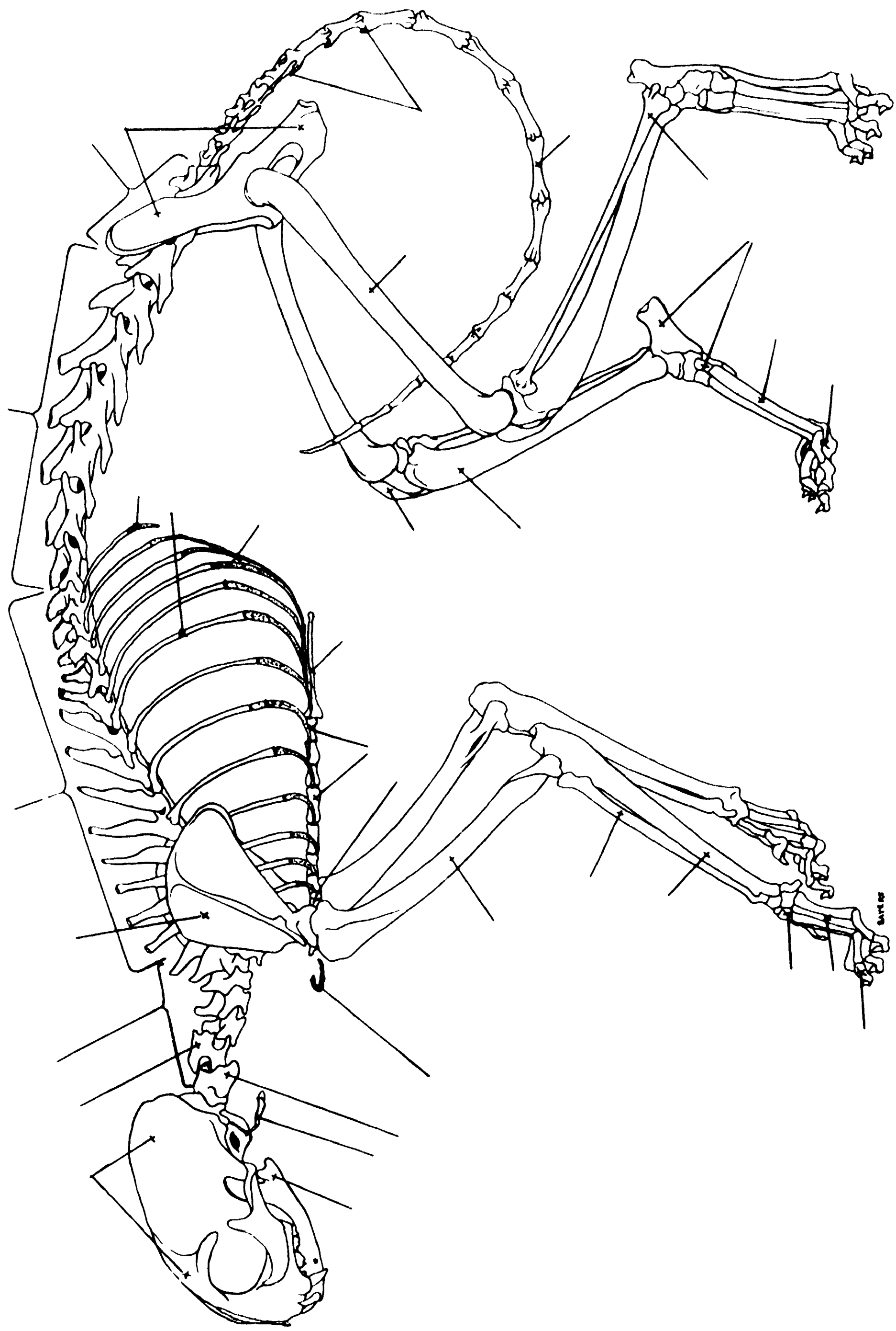

Skeleton of the cat*

*From Harrison, Bruce M.: Manual of Comparative Anatomy, St. Louis, 1959, The C. V. Mosby Co.

tendinae are tough cords attached to the walls of the ventricles and the auriculoventricular valves to prevent the valves from "turning inside out."

Venous system

Locate the **right auricle** and observe the **precaval vein (descending,** or **anterior, vena cava)** leading into it and returning blood from the anterior parts of the body. Observe a pair of **internal mammary veins** which return blood from the mammary glands and empty into the precaval vein just anterior to the auricle. Note that the precaval vein is formed by the union of the very short **right** and **left innominate veins.** Each innominate vein receives (1) an **internal jugular vein** running near the trachea (windpipe) and returning blood from the brain case, sinuses, etc.; (2) an **external jugular vein** running superficially in the neck and returning blood from the face, ears, jaws, etc.; and (3) a **subclavian vein** returning blood from the forelimbs (in some specimens more than one subclavian vein may be present).

Also emptying into the right auricle is the **postcaval vein (ascending,** or **posterior, vena cava)** which returns blood from the posterior parts of the body. Trace this vein through the diaphragm and to the liver. Carefully dissect the liver tissue so as to observe the short **hepatic veins** which collect blood from the liver and carry it to the postcaval vein. Locate the paired kidneys and the **renal vein** coming from each and emptying into the postcaval vein. Just posterior to the paired renal veins are the **gonadal veins** which return blood from the gonads (reproductive organs).

In the region of the pelvis note that the postcaval vein receives two large **common iliac veins** which return blood from the hind limbs. Each common iliac vein receives (1) an **internal iliac vein** returning blood from the urinary bladder, rectum, genital organs, etc., and (2) an **external iliac vein** returning blood from the hind limbs.

Examine the membranous mesenteries in the region of the liver and locate the **hepatic portal vein** carrying blood from the digestive tract to the liver where it is filtered and carried to the postcaval vein by the hepatic veins (previously described). Observe the branches of the **hepatic portal vein;** they are (1) the **gastric vein** from the stomach, (2) the **splenic vein** from the spleen, (3) the **anterior mesenteric vein** from the intestine.

Locate the **umbilical vein** within the umbilical cord and trace it to the liver where it is now known as the **ductus venosus.** Dissect the liver tissue carefully and follow the ductus venosus to the **postcaval vein (ascending,** or **posterior, vena cava).**

Arterial system

Arteries anterior to heart. Locate the **left ventricle** and the large **aorta** which arises from it. Numerous arteries arise from the aorta, among them being (1) the **coronary artery,** which supplies the heart muscles and can be seen by pushing the auricles aside. (2) The next large branch arising from the aorta is the **brachiocephalic artery,** which branches into (a) the **right subclavian artery,** supplying blood to the right forelimb, and (b) the **bicarotid trunk,** which soon branches into the **right** and **left common carotid arteries.** From the right subclavian artery arises the **internal mammary artery** which courses down the midventral thoracic wall to supply the right mammary gland.

Again locate the **right common carotid artery** and dissect away the muscles at the base of the skull carefully. At about this point the common carotid artery gives off (1) a deep branch, the **internal carotid artery,** supplying the brain, and (2) a more superficial branch, the **external carotid artery,** supplying the tongue, face, etc.

Again locate the point where the brachiocephalic artery leaves the aorta. The next artery leaving the aorta is the **left subclavian artery,** which supplies the left forelimb.

Arteries posterior to heart. Push the lungs and other visceral organs to one side and trace the **aorta** as it passes posteriorly and gives off numerous small **costal arteries** supplying the ribs. Trace the aorta until you find a single **coeliac artery** arising from the midventral surface of the former. Tissues may have to be dissected carefully in order to see this artery as it supplies many of the abdominal viscera. The **coeliac artery** branches to form the following arteries: (1) **gastric,** to the stomach; (2) **hepatic,** to the liver; (3) **pancreatic,** to the pancreas; (4) **splenic,** to the spleen.

Just posterior to the coeliac artery is a single **superior mesenteric artery** supplying the small intestine. This can be seen by pulling out the small intestine and observing the many branches of the superior mesenteric artery in the mesentery which holds it.

Locate the large paired kidneys embedded in the dorsal abdominal wall. Observe the **right** and **left renal arteries** supplying the kidneys with blood. Do the right and left renal arteries come off the aorta opposite each other? Compare this in other pigs at your table.

Posterior to the renal arteries is a single **inferior mesenteric artery** supplying the large intestine. Continue to trace the aorta posteriorly and note that it has two paired branches. The more anterior pair are the **external iliac arteries,** which may be observed by separating the muscles as they supply the hind limbs. The more posterior pair are the **internal iliac arteries,** which continue into the umbilical cord as the **umbilical artery.**

Pulmonary circulation (to and from the lungs)

Locate the **right ventricle** and observe the **right** and **left pulmonary arteries** which carry blood to the lungs to be oxygenated. Locate the **pulmonary veins** which return the oxygenated blood to the **left auricle.** Note the large size of the **right and left pulmonary veins.** Note that the pulmonary artery is ventral to the aorta.

Observe carefully that the short vessel, the **ductus arteriosus,** connects the aorta and the pulmonary artery. During fetal life this ductus arteriosus shunts blood from the pulmonary artery into the aorta. At birth the ductus arteriosus collapses, sealing off the passage from the pulmonary artery to the aorta, thus causing the blood from the right ventricle to go to the lungs by way of the pulmonary arteries. What is the advantage in having the ductus arteriosus in the fetus?

RESPIRATORY SYSTEM

A pair of **external nares (nostrils)** at the tip of the nose lead to the **nasopharynx** (opening of nasal chambers into the pharynx). An opening, the **glottis,** leads to the **larynx (voice box),** which has two shelflike **vocal folds** for sound production. A cartilaginous **epiglottis** near the glottis shuts off the latter when food is swallowed. The openings to a pair of **eustachian tubes** are located on the anterior part of the dorsal wall of the pharynx. These tubes lead to the middle ear and assist in equalizing air pressure in the ear. Beyond the larynx is the **trachea (windpipe)** supplied with semirings of cartilage to keep the tube open. The trachea divides into the **right** and **left bronchus,** each of which divides into numerous **bronchioles** to form the **"bronchial tree"** of the lungs. Each of these smallest branches ends in a thin-walled, saclike **alveolus** through which oxygen and carbon dioxide are exchanged from the blood vessels of the lungs.

EXCRETORY SYSTEM

Two bean-shaped **kidneys** lie in the middorsal region of the abdominal cavity, just outside the membranous **peritoneum** which lines the cavity. A pair of tubular **ureters** pass the urine to the **urinary bladder** from which it is carried through the **urethra** to the outside by way of the **genital opening.**

Carefully remove a kidney and section it lengthwise. Internally each kidney has an outer **cortical layer** and an inner **medullary layer.** The cortical layer appears granular because of numerous, microscopic **malpighian corpuscles.** These and other microscopic structures should be studied from prepared slides of the kidney. In each malpighian corpuscle is a knot of small capillaries, called a **glomerulus,** which is surrounded by a thin-walled **Bowman's capsule.** Wastes are brought to the corpuscles by blood vessels and they are excreted there. **Renal tubules** collect the wastes from the malpighian corpuscles and pass them into **collecting tubules** which in turn pass them into the basinlike **pelvis of the kidney.** From the latter the urine passes into the ureters.

The **medullary area** appears radially

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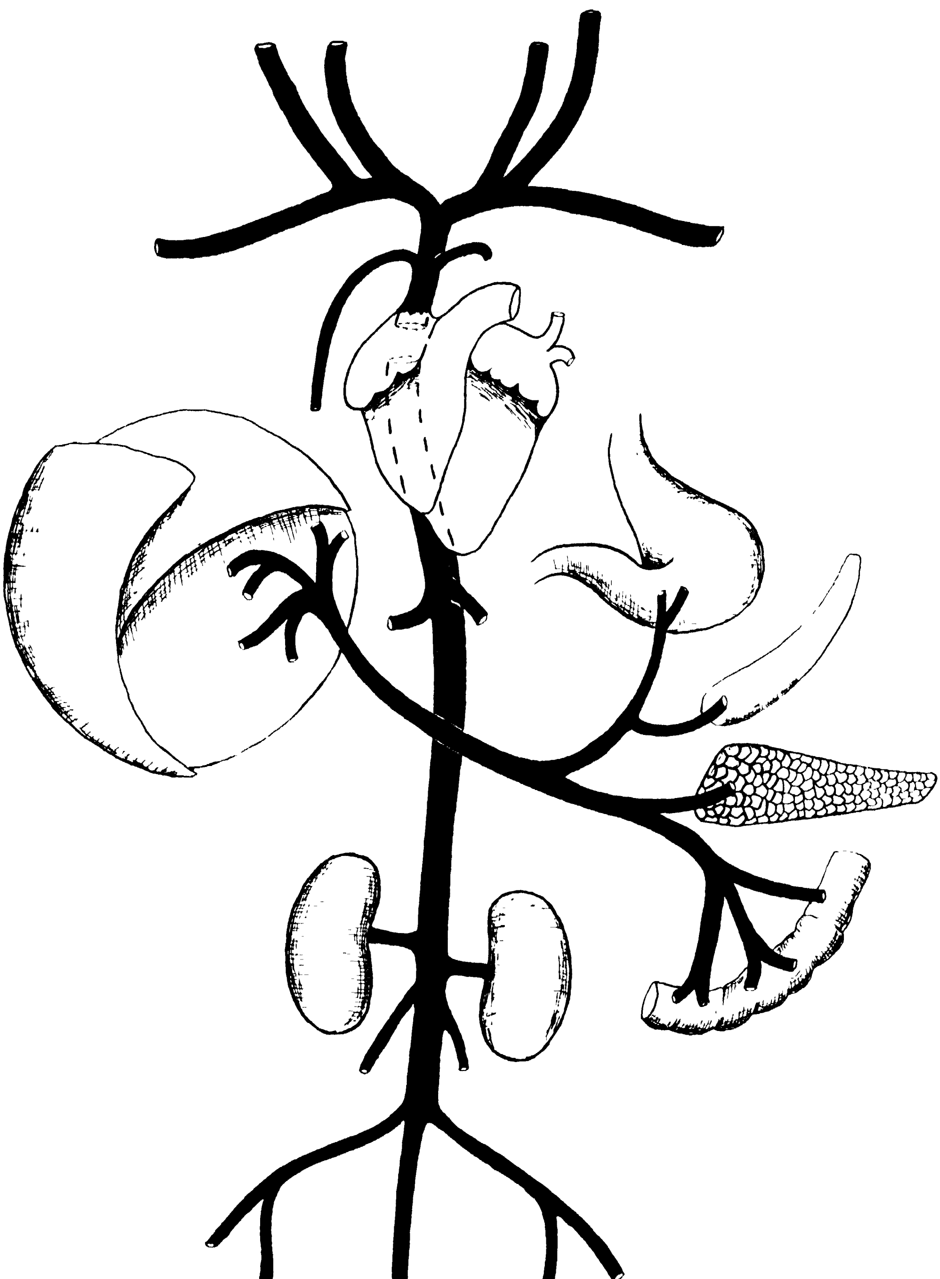

Venous system of the fetal pig

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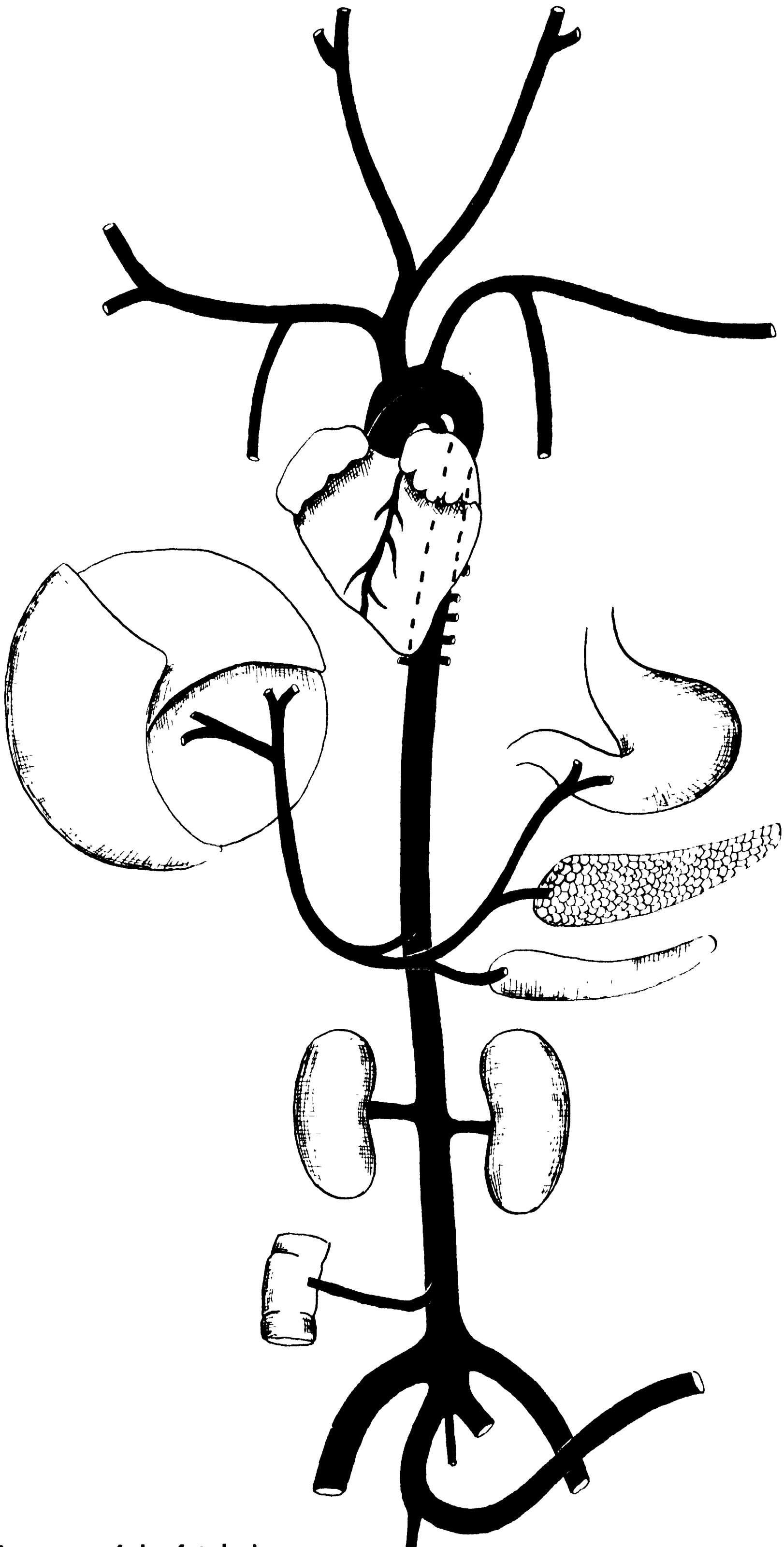

Arterial system of the fetal pig

striated because it is composed of many cone-shaped **renal pyramids.** Possibly the internal structure may be understood better by a study of the kidney of a mammal such as the beef or cat, or at least from models and charts of man which show the detailed structures.

NERVOUS SYSTEM

Remove the skin and muscles from the dorsal and lateral sides of the head and **carefully** dissect away the skull bones (from dorsal side) so as not to damage the soft brain. Observe that the brain is protected by three membranes known as **meninges.**

Remove the meninges with great care and observe the convolutions of the two **cerebral hemispheres (cerebrum).** Note the pair of large **olfactory lobes** which extend anteriorly from the cerebral hemispheres and serve as centers of smell. The rather large **cerebellum** lies posterior to the cerebrum and contains fine elevations and furrows. A **medulla oblongata** is the posterior part of the brain which connects with the spinal cord. A **pons,** composed of a transverse band of fibers, lies just anterior to the medulla.

If the brain of a fetal pig is too soft for study, substitute a specially hardened brain of a cat, sheep, or human being, or use models and charts.

If desirable, carefully remove the entire brain from the cranium, being careful to preserve all parts, including the **12 pairs of cranial nerves** which originate from the brain. Attempt to identify as many of these as suggested by the instructor. A ventral view of the brain, in addition to the parts suggested above, should reveal the **optic chiasma** which is a crossing of the **optic tracts** on the ventral surface of the cerebrum. Observe the ductless gland, the **pituitary (hypophysis),** which is a stalked body on the ventral surface of the brain just posterior to the optic chiasma.

Cut away the skin and muscles which cover the vertebrae of the spinal column. Carefully remove (bit by bit) the vertebrae which surround the spinal cord until it is exposed. Note that the cord is enlarged in the cervical and lumbar regions. Observe the threadlike **filum terminale** with which the cord ends in the sacral region. Observe as many as possible of the 33 **pairs of spinal nerves** which originate from the spinal cord.

SENSE ORGANS

A pair of **eyes** have **upper** and **lower lids.** A whitish, **third eyelid (nictitating membrane)** in the inner corner of each eye helps to keep the eye clean. An oval **lacrimal gland** in the lateral corner of each eye secretes a liquid to keep the eye clean.

If desirable, carefully remove the eye (or study a preserved eye, or model), noting the pairs of **eye muscles** which hold it in its socket and cause it to move. The **pupil** of the eye permits the entrance of light waves and is surrounded by a colored, circular **iris.** An external, whitish covering of the eye is the **sclera (sclerotic coat).**

Internally the eyeball contains a **lens** with its **ligaments** to focus the light on the light-sensitive **retina** upon which images are recorded. An **aqueous humor** is exterior to the lens and is covered by the **cornea.** A **vitreous humor** fills the inner cavity of the eyeball and the two humors maintain the proper pressure within the eyeball.

A pair of cartilaginous **external ears (pinnae)** receive sound waves which are conducted through the **auditory canal** to the **tympanic membrane (ear drum)** and then to the **middle ear (tympanic cavity).** Within the cavity are **ear bones,** or **ossicles** (known as hammer, anvil, and stirrup bones), which connect with the **inner ear.** From the latter the impulses are sent over the **auditory nerve** to the proper brain center. A pair of **eustachian tubes** lead from the pharynx to the middle ear to assist in equalizing air pressure on both sides of the eardum.

A pair of **external nares (nostrils)** lead to the **nasopharynx** (opening of the **nasal chambers** into the pharynx). Sensitive **epithelial cells** in the nasal chambers may be affected by certain substances, giving a sense of smell when the impulses are sent to the **olfactory lobes** of the brain.

ENDOCRINE (DUCTLESS) GLAND SYSTEM

The glands of this system do not have ducts to transport their secretions, but each is supplied with food by its artery and has its secretions transported from it by its vein. These glands are similar to those of other mammals. If desirable, those of other animals (or models or charts) may be substituted. Some of them to be studied in the fetal pig include the thyroid, thymus, adrenals, pituitary, pineal body, and pancreas.

1. The **thyroid** is an oval, reddish gland located near the base of the neck.
2. The **thymus** is located in the neck and thorax and is composed of two parts.
3. The **adrenals** are elongated glands on the anterior part of each kidney.
4. The **pituitary (hypophysis)** is a stalked body on the ventral surface of the brain just posterior to the optic chiasma.
5. The **pineal body** is located between the cerebrum and cerebellum.
6. The **pancreas** is located between the stomach and small intestine, and certain internal structures known as **isles of Langerhans** produce an endocrine secretion which is carried away in the blood. (Other cells of the pancreas secrete the digestive pancreatic juice carried to the small intestine by a small pancreatic duct.)

Other endocrine glands and their functions should be studied by referring to their considerations in the text or other references.

REPRODUCTIVE SYSTEM

Male

Identify two baglike **scrotal** sacs located at the posterior part of the animal between the hind limbs. Each scrotal sac containing a **testis** with its small, coiled mass of tubules, the **epididymis,** which almost surrounds the testis.

Internally the testis has many **seminiferous tubules** to produce and transport **sperms**. The seminiferous tubules are connected with the epididymis which leads into the vas **deferens (sperm duct)**. The vas deferens passes through the inguinal canal into the abdominal cavity and enters the **urethra.** Two glandular **seminal vesicles** are attached to the urethra near where the vas deferens enters the urethra. Carefully remove the mesenteries to expose these structures. A small **prostate gland** between the seminal vesicles may be poorly developed in the fetal pig. Two enlarged **Cowper's glands** lie just anterior to and on either side of the junction of the urethra and penis. A long, muscular **penis** lies beneath the skin and extends anteriorly between the hind limbs toward the **urogenital opening.** The latter lies posterior to the umbilical cord. The canal in the penis conducts urine and sperms. In order to follow the urethra to the penis and then to the genital opening it is necessary to cut through the pubic bones of the pelvis. Great care must be taken in doing this so as not to damage the underlying soft tissues.

Female

Two whitish **ovaries** are located dorsally near the posterior end of the abdominal cavity. The ovaries contain **graafian follicles** in which **eggs** develop and when mature they appear on the surface of the ovary. A small coiled **fallopian tube (uterine tube)** lies near each ovary. One end of each tube is funnel shaped and receives the egg as it breaks from the ovary into the **coelom (body cavity).** The two uterine tubes enlarge and unite to form the **two horns** of the **uterus (womb).** A muscular tubelike **vagina** is continuous with the uterus. The vagina and urethra empty into the **urogenital sinus** which may have a small, fingerlike **clitoris** on its ventral floor. The clitoris is an erectile organ homologous with the male penis. The **urogenital opening** is located ventral to the anal opening. Two rows of **mammary glands** (5 to 7 glands per row) are beneath **nipples (teats)** on the skin on the ventral surface of the abdomen.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies made with sufficient accuracy to supply additional information which was pertinent in the solution of the problems? If you think you may have made errors, give reasons why you made them.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the information available? RECORD additional conclusions which may not be associated directly with the problems. Did any additional problems occur to you as you studied the pig? If so, did your information solve them? Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions. How carefully did you make your observations and how often did you repeat them? Did you actually observe all the things described or did you "guess" at certain ones? Is the latter attitude really scientific? Do you follow this same undesirable procedure when you solve other problems?

Biology of man (anatomy and physiology)

1. Problems

Does the human body have systems which perform functions comparable to those of lower animals, even though they may be relatively more complex in man? Are there any systems in man that are not common to lower animals? Does man have a "closed" circulatory system similar to that of other vertebrates? In what ways is a human body superior to those of other vertebrates? Upon what basis is the efficiency of a system determined, and, consequently, can we say that all of the systems of man are the most efficient in the animal kingdom? Is the vocal apparatus a desirable addition to the human respiratory system? Does the human body have several methods of eliminating the various types of wastes? Is the lymph system a desirable adjunct to the circulatory system, and what functions does it perform? What characteristics of mammals does man possess? Why is the four-chambered heart of mammals and birds a highly desirable type of organ? Is the human endocrine (ductless) gland system complex and efficient from the standpoints of development, coordination, and behavior?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information which you may have concerning the structures and functions of the human body which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From your accurate information which pertains to the problems formulate hypotheses from which you may work in their solution. RECORD methods of investigation which will supply additional pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Much information concerning the structures and functions of the human systems can be learned by careful studies of models, charts, skeletons, museum preparations, lantern slides, film strips, movies, etc. Attempt to secure as much information as possible about the anatomy and physiology of each system as you fill in the blanks on the accompanying pages. Be sure that you fill in all blanks accurately and that you remember all the facts. **Do not limit your information to that which is required to fill in the blanks.** The questions asked are for the purpose of directing your reading in the collection of information concerning the different systems of the human body.

Make DRAWINGS which you think may be helpful in remembering certain facts.

Classification of man

Phylum **Chordata** (kor-da'ta) (L. *chordatus,* having a rodlike notochord)

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A. Integument (skin) and skeleton of man

(1) The two major layers of the human skin are (a) ______________________ (______________________) and (b) ______________________ (______________________).

(2) Nails, hair, etc., are modifications of the ______________________ tissue.

(3) The production of oils in the human skin is due to ______________________ glands.

(4) When we "peel" after a sunburn, the shed tissue is ______________________ tissue.

(5) The substance in the outer layer of the epidermis to prevent excess loss of water is called ______________________.

(6) The dermis is attached to the deeper tissues by a type of connective tissue known as ______________________ tissue.

(7) The layer of skin which is characteristic of vertebrates and which is used when leather is "tanned" is the ______________________.

(8) The tubelike structure from which a hair grows is called a ______________________.

(9) Teeth are derived embryonically from the ______________________ tissue.

(10) The hard, outer covering of a tooth is called ______________________.

(11) The softer, inner part of a tooth is called ______________________.

(12) The last pair of molar teeth have the erroneous common name of ______________________ teeth.

(13) The total number of permanent teeth in an adult is normally ______________________.

(14) The so-called ______________________ glands in the skin eliminate their excretions through pores in the skin surface.

(15) The average normal body temperature is approximately ______________________° F.

B. Motion and locomotion

(1) The number of scientifically named muscles of man total over ______________________.

(2) The total musculature of man contains over ______________________ muscle cells.

(3) The hundreds of delicate fibrils in muscles are composed of a lineal series of alternate ______________________ and ______________________ areas (bands).

(4) A muscle which is controlled by the will is said to be ______________________.

(5) The end of a muscle which is more or less solidly attached is called the ______________________, whereas the more movable end is called the ______________________.

(6) Muscles which move a structure away from the median line are called ______________________ muscles, whereas those which move a part toward the median line are called ______________________ muscles.

(7) When muscles are not actively contracting they are not completely relaxed, but are partially and constantly contracted because of a phenomenon known as ______________________.

(8) The time interval between the stimulus application and the start of visible muscle contraction is called a ______________________ period.

(9) Sustained contractions of muscles caused by a series of stimulations, without intervening relaxations, are known as ______________________.

(10) Two proteins in muscles are ______________________ and ______________________.

(11) The many, unnamed muscles which compose the viscera (internal organs) are called ______________________ (______________________) muscles.

(12) The indistinctly striated muscles which compose the walls of the heart and arteries are called ______________________ muscles.

(13) Muscles which are not under the direct control of the will are called ______________________ muscles.

C. Foods and nutrition

(1) The enzyme produced by the salivary glands in the human mouth is called ______________________ (______________________).

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(2) Two enzymes present in the gastric juice of the stomach are called (a) ______________ and (b) ______________.

(3) Organic compounds which are essential and were originally called "accessory growth factors" are commonly known as ______________.

(4) The so-called "anti-infection" vitamin is known as vitamin ______________.

(5) The so-called "blood clotting" vitamin is known as vitamin ______________.

(6) About two thirds of the human body is composed of the inorganic chemical ______________.

(7) The disease called rickets is due to a deficiency of vitamin ______________.

(8) The three pairs of salivary glands are called (a) ______________, (b) ______________, and (c) ______________ glands.

(9) The anterior part of the stomach is called the ______________ part, whereas the posterior part is called the ______________ part.

(10) The first part of the small intestine is called the ______________.

(11) The inner walls of the small intestine are covered with great numbers of small, finger-shaped structures called ______________ for absorption purposes.

(12) The enlarged pouchlike structure at the junction of the small and large intestines is called the ______________, and the latter contains a pencil-shaped ______________.

(13) The largest gland in the human body is the ______________.

(14) The liver manufactures ______________ which is stored in the ______________.

(15) An important organ of digestion which lies between the stomach and small intestine is called the ______________.

D. Circulation in man

(1) The upper chambers of the heart are called ______________ (______________) whereas the lower, more muscular chambers are called ______________.

(2) Blood is pumped to all parts of the body from the ______________ ventricle.

(3) The part of the circulatory system which supplies the various parts of the body is called the ______________ circulation, whereas the part which carries blood to the lungs to be oxygenated is called the ______________ circulation.

(4) The heart is enclosed by a membranous sac known as the ______________.

(5) In a heartbeat the contraction phase is called the systole, whereas the relaxation phase is called the diastole, and the two constitute what is known as a "______________."

(6) Normally a human heart beats about ______________ times per minute.

(7) Blood vessels which carry blood away from the heart are called ______________, whereas those which carry blood toward the heart are called ______________.

(8) Thin-walled vessels which form a network connecting arteries and veins are called ______________.

(9) The red blood corpuscles are scientifically called ______________, whereas the white blood corpuscles are called ______________.

(10) Small, colorless disks which are associated with blood clotting are called ______________.

(11) Blood clotting is initiated by juices from injured tissues and disintegrating blood platelets through the action of enzymes collectively called ______________.

(12) The network of insoluble protein fibers known as ______________ assists in clot formation.

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Date ______________________

(13) A clot formed in a blood vessel which is not severed is called a ______________.

(14) The composition of the ______________ is similar to that of the blood plasma, and ranges from colorless to yellowish color, and contains no platelets.

(15) Enlargements of lymph ducts are known as lymph ______________.

E. Respiration in man

(1) The supplying of oxygen to body cells and the removal of carbon dioxide is known as the process of ______________.

(2) The rhythmic inhalation of air into the lungs and the exhalation of carbon dioxide and other gases may be defined as ______________.

(3) In adults during rest the normal rate of breathing varies from ______________ to ______________ times per minute, although these figures vary with individuals and circumstances.

(4) The total inner surface of the human lungs is estimated to approximate ______________ square meters.

(5) The voice box, or "Adam's apple," is scientifically called the ______________.

(6) The common cavity which connects the nasal cavities with the larynx, as well as the mouth with the esophagus, is called the ______________.

(7) The two major folds in the larynx which are associated with sound production are called the true ______________ ______________ (______________ ______________).

(8) Each bronchiole within the lung terminates in a saclike structure called an ______________.

(9) Each lung is enclosed in a serous sac called the ______________, an inflammation of which is known as ______________.

F. Excretion of wastes

(1) The pair of bean-shaped ______________ located in the back of the abdominal cavity select wastes from the blood brought to them and pass the wastes through the ______________ ______________ to the urinary bladder where they are stored.

(2) When examined microscopically, the cortex of the kidney contains numerous globelike ______________ (______________) corpuscles.

(3) Each unit in the above question is composed of a coiled mass of capillaries which are known collectively as a ______________.

(4) The quantity of urine secreted in twenty-four hours varies, but the normal average for a healthy adult is ______________ to ______________ cubic centimeters.

(5) The urinary bladder normally holds about ______________ pint.

(6) Muscular contraction of the bladder forces the urine to the exterior through the ______________ ______________.

G. Coordination in man (including endocrine glands) and sensory equipment

(1) A structure which is adapted to respond to stimuli of a specific type is called a ______________ ______________.

(2) Receptors which are adapted especially to be stimulated by suitable concentrations of definite, chemical substances are called ______________.

(3) Human auditory receptors (hearing) are vibrating "hair cells" located in the coiled ______________ ______________ (resembling a snail shell) of the inner ear.

(4) Sound waves enter the external ear and vibrate the ______________ (______________ ______________) which transmits vibrations along the bones of the middle ear.

Name ______________________

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Date ______________________

(5) The bones of the middle ear are (a) ______________ (______________), (b) ______________ (______________), and (c) ______________ (______________).

(6) Pressure receptors called ______________ corpuscles are abundant in the outer skin layers of most parts of the human body.

(7) The reactions which make us aware of our muscular movements are called the ______________ sense, or ______________ sense.

(8) Images are formed on the retina of the eye on the sensitive cells specifically called ______________ and ______________.

(9) Effectors in man are mainly (a) ______________ for secretion and (b) ______________ for movements.

(10) Glands which are ductless and distribute their secretions by means of the blood are called ______________ glands.

(11) The thyroid glands produce a protein hormone called ______________, whose active part is the amino acid called ______________.

(12) When hypothyroidism is present from birth the disease is called ______________.

(13) Two pairs of endocrine glands which are attached to the thyroids are called ______________.

(14) The bilobed endocrine gland attached to the under side of the brain is called the ______________ gland.

(15) The male sex hormone produced by the testes is called ______________.

(16) Two female hormones produced by the ovaries are (a) ______________ and (b) ______________.

(17) The islets of Langerhans in the pancreas secrete the hormone ______________ which is associated with the metabolism of sugar.

H. Human reproductive system

(1) Sperms are produced by the many ______________ tubules in the testes.

(2) The number of sperms discharged at any one time normally may be about ______________ millions suspended in a small amount of seminal fluid.

(3) Female eggs are produced in a pair of oval ______________ in the lower abdomen.

(4) The embryo develops in a pouchlike ______________.

(5) The inner lining of the uterus is called the ______________ and the fertilized egg may adhere to it.

(6) When a female produces and matures an egg in the ovary for the first time the period of sexual maturity called ______________ is said to have occurred.

(7) Each developing egg in the ovary is contained within a ______________.

(8) When an egg is mature, the graafian follicle ruptures the wall of the ovary and deposits the egg in the ______________ (______________), from which it passes into the fallopian tube.

(9) Egg production occurs at regular, periodic intervals and the series of interrelated phenomena, including the preparation of the uterus for the implantation of the fertilized egg, is called the ______________ cycle.

(10) If the egg is not fertilized, the superficial mucous layer of the uterus is shed and accompanied by rupturing of blood vessels (hemorrhage) which ends in ______________ in which tissues and blood leave the uterus through the vagina.

Subphylum **Vertebrata** (vur te-bra'ta) (L. *vertebratus*, jointed)

Class **Mammalia** (ma-ma'li a) (L. *mamma*, breast or milk glands)

Order **Primates** (L. *primus*, high rank)

Suborder **Anthropoidea** (an thro-poi' de a) (Gr. *anthropos*, man; *eidos*, like)

Family **Hominidae** (ho-min'i de) (L. *hominus*, man)

Genus **Homo** (L. *homo*, man)

Species **sapiens** (sa'pi ens) (L. *sapiens*, to know, have sense)

Races of Man—Caucasian, Mongolian, Negro, etc.

Varieties of Caucasians—Nordic, Alpine, Mediterranean

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and detailed to provide additional, pertinent information? If you think that you made errors, give reasons why they were made. Suggest specific ways by which additional, accurate information might be secured.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the available information? RECORD additional conclusions which may not be associated directly with the problems. Do you feel that you have a satisfactory knowledge of the anatomy and physiology of the human body? In what ways are there improvements of human body systems over comparable ones in lower types of animals? Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions. Did you make your observations carefully and did you repeat them sufficiently to guarantee accuracy? Did you actually observe all things described or did you "guess" at certain ones? Is the latter attitude really scientific?

Living plants and animals contrasted

1. Problems

Is it relatively easy to distinguish between higher plants and animals but more difficult to do so between lower plants and animals? What are some of the difficulties in distinguishing between certain lower plants and animals? Do all living organisms, plants and animals, possess many basic and fundamental similarities in common which are necessary for life in each group? When various kinds of waters are studied, might different types of plants and animals be found in each? In general, may there be interdependence and a balance between the chlorophyll-bearing plant life and animal life in certain waters? What are the basic criteria for distinguishing plants and animals as might be found in waters?

2. Preliminary observations and pertinent data and information

RECORD accurately all information which is true and which pertains specifically to the problems. The reading of selected references in connection with the problems may be beneficial.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable information that pertains to the problems, formulate hypotheses from which you may work toward their solution. RECORD specific methods and procedures whereby additional, reliable information and data may be secured.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Previous studies have been made of various types of plants and animals and probably less difficulty has been encountered in distinguishing the higher types of both groups. However, in order to review similarities and differences, as well as to secure additional knowledge concerning these two groups, it may be desirable to make studies of the living organisms (especially the smaller forms) in various types of fresh water.

Collect by means of proper nets or other equipment the living organisms to be found in (a) a small pond, (b) a lake, and (c) various types of streams which have been selected for this particular study. Place the collected materials from different kinds of waters in separate, clean bottles, labeling each bottle and recording the specific region from which each sample was taken. Accurately locate each sampling station in case you need to secure additional samples for rechecking purposes. Accurately RECORD all pertinent data which pertain to each sampling station.

With a clean medicine dropper place some of each sample in a watch glass and examine with a hand lens. Prepare slides from each sample and examine microscopically, using a binocular microscope for the larger forms. Make DRAWINGS and careful NOTES of each type of living organism found. Attempt to identify all organisms by consulting such references as supplied by the instructor. If in doubt about a certain organism, restudy it from the same sample. Repeat the above procedure for each sample from the different types of water, attempting to study as many different kinds of plants and animals as possible and NOTING THE SIMILARITIES AND DIFFERENCES BETWEEN PLANTS AND ANIMALS.

After you have studied and identified numerous living plants and animals in different types of water, what traits did all the plants have in common? What traits did all the animals have in common? What basic differences between such aquatic plants and animals can you give? What basic traits did all the plants and animals have in common?

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were all observations and interpretations made accurately? List instances in which errors may have been made and reasons why they were made.

6. Drawing logical conclusions based on data and facts obtained

RECORD the conclusions which you can draw from the logical interpretation of the data and information. List additional conclusions which may not have been associated directly with the problems. Be sure that all conclusions are valid and based upon sufficient, reliable evidence.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations so that the information and data are as reliable as possible and that conclusions are accurate as based on the information secured. After rechecking carefully what are the basic differences between aquatic plants and animals as revealed by your studies? What are the basic and fundamental traits which such aquatic plants and animals have in common?

Part Four

BIOCHEMICAL AND BIOPHYSICAL PHENOMENA IN PLANTS AND ANIMALS

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Additional biochemical and biophysical phenomena in plants and animals

1. Problems

Do semipermeable membranes permit the passage of certain molecules through them while preventing the passage of other molecules, and is this of importance in living organisms? Can water loss due to osmosis result in the shrinking away (plasmolysis) of the protoplasm from the cell wall, and is this important in living organisms? Do molecules and ions have the ability to diffuse (scatter) until a rather uniform distribution results, and is this of importance in living organisms? How are certain substances conducted (transported) by certain tissues of living organisms? Do plants lose water by a process known as transpiration? Does the phenomenon of respiration occur in both plants and animals? In the process of photosynthesis are such factors as light, chlorophyll, carbon dioxide, and water essential, and what does each contribute? Do certain living organisms display the phenomenon of bioluminescence? Are there various kinds of pigments present in certain plants, whose presence make it possible for them to perform some of their activities? Are there various types of pigments present in certain animals which serve numerous functions in their life activities? Do certain types of organisms produce and receive sounds and for what purposes? Are certain plant responses due to the production of plant hormones? Can the viability of seeds be ascertained and of what value is this to man? Does the protoplasm of plants and animals produce a number of enzymes for many different functions? How can the blood types of man be ascertained and of what importance is this? Do animals and plants possess the characteristic of irritability (susceptibility to stimulation) in various degrees, depending on the species? Do living organisms have an inherent tenacity of life, depending on the species?

2. Preliminary observations and pertinent data and information

RECORD accurately all information which you know to be true and which pertains specifically to the problems. Read references in this connection.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD specific methods for securing additional, pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data and information

There are many biochemical and biophysical phenomena in plants and animals, only a few of which may be illustrated by the following experiments and studies.

PERMEABILITY OF MEMBRANES AND OSMOTIC PRESSURE

The passage of water molecules through a semipermeable (differentially permeable) membrane illustrates the phenomenon of osmosis, and the pressure produced by the process is called osmotic pressure. Water is a universal constituent of protoplasm and thus is a common solvent in which chemical reactions and metabolic activities occur.

Osmosis may be demonstrated experimentally by an apparatus known as an osmometer. Soak in water a piece of bladder (or similar membrane) about 4 inches square. Securely cement and tie the membrane across the large end of a thistle tube. When thoroughly dried, fill the bowl and about 1 inch of the tube with a 20% aqueous solution of sugar, using a medicine dropper with a small bore. By means of a clamp and stand, suspend the thistle tube in a beaker of distilled water so that the level of the sugar solution and the water are equal.

Measure and RECORD the level at 20-minute intervals. Explain the results, taking into consideration that molecules are in constant motion and that sugar molecules are much larger than water molecules. How could you prove that sugar molecules have not passed through the membrane? List several examples in living organisms which illustrate osmosis.

Remove a circular area (30 mm. diameter) from the shell of the blunt end of an egg, being careful not to break the membrane beneath. Support the egg in a beaker of water which does not come quite up to the broken edge of the shell. Compare the contour of the unbroken membrane at the beginning and end of the laboratory period. Note the difference in pressure which exists when a liquid is separated from water by a permeable membrane.

Wash the soil from a medium-sized red beet. Cut three similar slices about ¼ inch thick and wash carefully in cold water. Place one slice in a petri dish of tap water. Place another slice in a petri dish of 10% salt solution. Place the third slice in boiling water for about 1 minute to kill the cells and then place in a petri dish of tap water. Note that the red pigment (anthocyanin) is present in the cell sap. Examine in an hour, explaining the results for each slice.

Cut a strip of dialysis tubing about 10 cm. long and hold it vertically under a stream of running water to separate the sides of the tubing. Twist one end of the tubing and tie securely with string to form a bag.

Fill the bag half full with a soluble starch solution. Tie the other end of the bag and rinse the outer surface under a stream of water. Immerse the bag in a beaker of water to which enough iodine solution has been added to give a brownish color.

What color changes occur? Did the iodine osmose into the bag? How do you know? Did starch osmose out of the bag? How do you know? List some of the results of osmosis in living plants and animals.

PLASMOLYSIS

Plasmolysis is a phenomenon in which protoplasm shrinks away from a cell wall because of water loss due to osmosis. This may be demonstrated experimentally by placing a leaf of the water plant **Elodea** *(Anacharis)* in a 5% aqueous solution of sodium chloride and examining microscopically. Should you examine an untreated leaf also? Why? Explain the shrinking of the protoplasm away from the cell wall, taking into consideration the fact that 5% salt solution is much more concentrated from an osmotic standpoint than protoplasm.

DRAW a plasmolyzed cell and contrast with a normal one.

Mount a filament of the green alga, *Spirogyra,* in water under a cover slip and observe the structure. Replace the water with a 15% solution of sugar, drawing the water out with a filter paper and adding the sugar solution at the opposite side of the cover slip. Observe differences in the position of the protoplasm in relation to the cell wall.

DRAW to show the plasmolyzed cell and contrast with a normal one.

With a pair of clean forceps carefully peel off a strip of the lower epidermis of a leaf of the plant *Rhoeo discolor,* which has the common name of "babes in a cradle" or "Moses in the bulrushes." Mount a small piece in water on a slide and mount a similar piece in 10% salt solution. Examine microscopically, noting the difference between the cells of the two mounts. Explain the results.

DIFFUSION

The ability of molecules and ions to scatter until a rather uniform distribution results is an example of diffusion. Diffusion results from the random, vibrating movements of particles, and there is a greater diffusion from regions in which they are more highly concentrated to regions where they are less highly concentrated.

Place equal amounts of water in two beakers of the same capacity. Place one beaker near a radiator (or lamp) where it will be heated slightly, and place the other beaker where it will not be heated above room temperature. Select 2 crystals of potassium permanganate of equal size and carefully drop 1 crystal into each beaker. Examine at intervals, noting the progressive diffusion.

Is there a difference in the rate of diffusion between the beakers? Why? Do similar phenomena occur in living protoplasm, and what benefits or detriments might result? What factors might enter into the problem, as to whether a particular diffusion phenomenon in protoplasm might be beneficial or detrimental? Explain any differences in the experiment which might be due to increased temperature.

CONDUCTION (TRANSPORTATION)

Place a so-called "stalk" of celery in a pan of water and remove (under water) 2 petioles of equal size. Carefully remove all of the leaflets (under water) from one petiole. Why should this be done under water? Quickly place the lower end of each petiole in a weak aqueous solution of a dye (safranin, eosin, or red ink). Each petiole contains vascular bundles (xylem and phloem tissues) for transportation purposes.

After about 30 minutes cut cross sections from each petiole, wash in water, and examine with low magnification to ascertain how far the dye solution has been conducted, noting the time interval and the length of tissue through which the dye has passed. Does the presence or absence of leaflets affect the rate of conduction? Explain.

Repeat the above, using stems of a plant such as *Coleus,* young corn plants, or similar elongated sections cut from a fresh potato.

Cut a long hole the size of a small earthworm in a cardboard. Moisten the cardboard and worm and place the latter in the hole and between 2 clean slides which are held in place by rubber bands. (Keep the worm moist.) Observe the conduction of blood with a low-powered microscope. What causes the flow of blood? What are the similarities and differences in conduction in the plants and the earthworm? Explain specifically.

TRANSPIRATION IN PLANTS

Seal 2 similar, well-watered plants in pots by wrapping each securely with aluminum foil (or wax paper or sheet rubber), tying all edges around the plant and pot tightly. Label plants A and B.

Weigh plant A accurately after being in the shade for 15 minutes. Weigh plant A after it has been in sunlight for 20 minutes. Weigh plant A after it has been in sunlight for 40 minutes.

Weigh plant B after it has been in the shade for 15, 20, and 40 minutes. What are the relative water losses? Is any weight loss due to water lost by transpiration only? Explain. What role does sunlight play? Explain.

Pass the long petiole of a vigorously growing leaf through a small hole in a cardboard which rests on a beaker containing water. Invert another beaker over the leaf. Observe the moisture given off by the leaf as it collects on the inner surface of the inverted beaker. Explain.

RESPIRATION

Place 5 drops of bromthymol blue indicator in each of 3 small clean test tubes. The indicator should be the same color in each tube, and, if not, wash the tube which shows an abnormal color. To each tube add a clean brass screw with the head up. To the first tube (A) add 4 germinating peas. To the second tube (B) add 4 germinating peas which have been killed by placing in boiling water for 4 minutes. Leave the third tube (C) without seeds. Stopper all tubes tightly. What is the variable factor in each? Observe at frequent intervals. Record changes in color of the indicator. What causes this change? Put a small amount of the indicator in another small clean tube. Blow your exhaled breath into it through a clean tube or straw. Does this help to explain the results secured above?

Exhale your breath through a clean glass tube or straw into a solution of clear lime water, $Ca(OH)_2$. If carbon dioxide, CO_2, is given off, it will combine with the lime water to form a precipitate of calcium carbonate, $CaCO_3$. Explain this phase of respiration. What similarities are there between respiration in plants and animals?

PHOTOSYNTHESIS AND LIGHT ENERGY

Importance of light in photosynthesis. Geranium plants were kept in complete darkness for over 24 hours before the experiment was started to permit the disappearance of starch from the leaves. So-called light screens were securely placed on the upper and lower surfaces of parts of several leaves. Designs were cut in the screens to permit light from several 150-watt reflecting (photography) bulbs to affect the leaf parts for about 3 hours, at a distance of about 3 feet.

After proper exposure a masked leaf and an unmasked (control) leaf are both tested for starch after the chlorophyll has been removed by placing them in alcohol which has been brought to a boil in a water bath on an electric hot plate. (CAUTION: NEVER BOIL ALCOHOL OR OTHER FLAMMABLE LIQUIDS OVER AN OPEN FLAME.)

The test for starch is done by adding iodine reagent to the treated leaves, and a blue-black color signifies the presence of starch. In what areas of the leaves is starch present? Explain why.

Make DRAWINGS to show the results of the experiment.

Importance of chlorophyll in photosynthesis. Make an accurate DRAWING of a variegated *Coleus* leaf or a variegated geranium leaf, showing the green and non-green areas accurately. Kill the cells by placing the leaf in boiling water for a minute. Extract the chlorophyll from the leaf by placing it in hot alcohol. (Heat in a water bath and NEVER OVER AN OPEN FLAME.) When the leaf is nearly clear, place it in a petri dish and cover with iodine reagent.

Make a DRAWING of the leaf showing the areas which display a positive starch test. Do these areas correspond with the green areas of your original drawing? Why?

Factors required for photosynthesis. Prepare jars (with tightly fitting tops) as suggested in Table 6 and place in the dark or sunlight, as stated. Each jar should contain a geranium leaf in a small vial of water (place only the petiole in the water). The geranium plants have been kept in the dark for 24 hours previous to the experiment. Why? The proper reagent is placed in the jars as stated and it should not come in contact with the leaf, and the vial with its leaf must remain upright in the bottom of the jar.

After 48 hours kill the leaves by immersing in boiling water. Extract the chlorophyll with warm alcohol (over an electric hot plate, NOT AN OPEN FLAME). Test

Table 6. Photosynthesis experiments

	Jar A	*Jar B*	*Jar C*	*Jar D*
Illumination	Sunlight	None	Sunlight	Sunlight
Leaf	Green	Green	Green	White or variegated
Reagent	5% $NaHCO_3$	5% $NaHCO_3$	10% NaOH	5% $NaHCO_3$

the leaves for starch with iodine reagent. $NaHCO_3$ (sodium acid carbonate) increases the amount of carbon dioxide (CO_2) available, and NaOH (sodium hydroxide) absorbs carbon dioxide. Explain the results obtained in each jar, including the factors responsible in each case.

Effect of light on living euglenae. Fill a clean glass tube with a culture of living, green *Euglena* (stoppered at both ends) and cover part of the tube with black paper. Expose to light and observe the distribution of the organisms. Explain. The locomotion may be decreased by adding 10% methyl cellulose (or an anesthetic, 5% chloretone).

BIOLUMINESCENCE AND LIGHT

Bioluminescence is a phenomenon of light production by living organisms as a result of certain chemical reactions. The light-producing substance is called **luciferin** and the enzyme, called **luciferase,** aids in the oxidation of the luciferin, producing "cold light," with about 1% of nonluminous heat rays. Luminescence is displayed by such animals as the firefly (beetle), the glow-worm (larva of a beetle), certain jellyfishes (as *Pelagia*), certain species of protozoans (as *Noctiluca*), certain squids and fishes, etc. Luminescence is also displayed by certain bacteria *(Photobacterium fischerii)* when growing under proper conditions and on proper food ingredients.

Study light emissions of such organisms as supplied, including detailed explanations of each phenomenon.

Light affects living plants and animals in various ways, as has been observed previously. Some organisms require light for their life activities, others require no light, whereas others are not affected either way. Mechanisms for the reception and interpretation of light are well developed in many higher animals, the degree of complexity and efficiency depending on the species.

Study models, illustrations, projected slides, museum specimens of eyes of such organisms as mollusks, insects, crustaceans, frogs, mammals, and man, noting the construction and functions of the various parts. Make labeled DRAWINGS to assist in remembering certain facts.

PLANT COLORATIONS

Cut up several green leaves of spinach and boil in water for a minute. Blot dry with paper towels. Extract the pigments by placing in alcohol which has been warmed on an electric hot plate. DO NOT BOIL FLAMMABLE LIQUIDS OVER AN OPEN FLAME. Let stand for 2 to 30 minutes. Fill a clean test tube about one-half full with the extract. Add benzene to fill the tube about three-fourths full. Place the thumb over the end of the tube and mix the liquids gently. Add a small quantity of water. Allow the liquids to separate. The water unites with the alcohol, reducing its solvent properties, but does not unite with the benzene. Consequently, the chlorophyll moves from the water-alcohol mixture and rises to the benzene at the top. The yellowish carotenoid pigments (carotene and xanthophyll) remain below. Were the carotenoids present originally? Observe the red color of the chlorophyll in reflected light and the green color in transmitted light.

The pigments can be demonstrated by **chromatography** as follows. Draw a line 1 inch from the edge of one of the longer sides of a filter paper (5 x 6 inches). By means of a fine capillary pipette transfer some of the pigment extract to the line on the paper which is placed on a table with the edge hanging over so as to allow the pigment to dry rapidly. Make the pigment mark about 4 inches long and allow it to dry. Repeat the applications until a deep green color is achieved.

Roll the paper into a cylinder and fasten the top corners (away from pigment line) with a paper clip or pin. Place the cylinder (pigment streak down) into a sealed jar containing 1 inch of petroleum ether-benzene mixture (1 part ether: 1 part benzene). Remove the paper before the liquid reaches the upper edge.

Examine the paper immediately, because the light tends to bleach the pigments. At the top of the solvent front are the orange-yellow carotenes. Next are the yellow bands of xanthophylls (usually two), then chlorophyll a (bluish) and finally chlorophyll b (yellowish green). These pigments are present in plastids.

Cut a leaf of red cabbage (or similar

source of anthocyanin pigment) into small pieces and place in a 500 ml. Erlenmeyer flask. Add distilled water and boil, noting the color of the cabbage after boiling. What explanation can you give for this?

Place equal quantities of the liquid in test tubes labeled 1 and 2. Add a little KOH, potassium hydroxide, or similar base to tube 1. Add a little hydrochloric acid, HCl, or similar acid to tube 2. Explain the differences in colors. Does anthocyanin act as an indicator to detect acidity or alkalinity?

ANIMAL COLORATIONS

Colorations in animals are produced by a number of chemical and physical means and serve a variety of purposes. In higher animals, particularly, pigments are produced in cells known as **chromatophores** of which there are several types. Stimuli may cause changes in the chromatophores, thus changing the coloration rather rapidly. In some animals the chemical pigmentations remain rather constant for long periods of time.

In some animals the coloration is due not only to the absorption of certain wave lengths of light by pigments or other substances, but also by the interference of light. A certain type of interference is known as **refraction** and is caused by the bending of the light rays as they come to our eyes, with the result that a variety of colors is produced. Another type of interference, known as **diffraction,** is caused by the separation of light into parts, thus producing different color sensations in our eyes. Examples of such color productions include the brilliant blue color of the tropical butterfly (*Morpho* sp.); the brilliant colors in certain feathers of birds; the colors in certain moths, butterflies, and various vertebrate animals.

Study such examples of animal colorations as supplied and attempt to explain the biochemical and biophysical phenomena involved in each, including the probable functions of such colorations for each organism.

PRODUCTION AND RECEPTION OF SOUND

The vibration of specialized equipments in certain higher animals produces sound waves which are borne to and interpreted by a specialized organ such as the ear. Lower animals do not produce sounds in the accepted sense, but they may be affected by sound waves.

In most insects which have sound-receiving mechanisms, there are also sound-producing (stridulating) organs. In the common locust there are two types of sound production. When at rest, certain species draw the femoral joint of the hind leg across a specialized vein of the wing cover to produce sound. When flying, they produce a crackling sound by rubbing the wings and wing covers together. Tympanic membranes connected by nerves to the nervous system probably act as "auditory" organs.

Study a locust, noting carefully the above structures.

In the cicada the male has a pair of large, ridged, parchmentlike drumheads on the first abdominal segment beneath the wings. The drumheads are vibrated by the action of muscles, and cavities within the body act as resonators. The female has no sound-producing apparatus.

Study a male cicada carefully, noting the above.

The female mosquito produces a characteristic sound by vibrating her wings 512 times per second. In male mosquitoes the hairs on the antennae are adjusted during flight so that the two plumelike antennae are stimulated equally by the wing sounds of the female, thus directing the male toward the female.

Study male and female mosquitoes, noting the above.

The degree of complexity of development of sound-producing and sound-receiving equipments in vertebrates varies with the species. In frogs there are sound-producing vocal equipments and sound-receiving mechanisms.

Study a frog, noting the above accurately.

In man there are highly developed sound-producing and sound-receiving mechanisms. The vocal cords (in the larynx) and the ear (external, middle, and internal ear) are complex and efficient.

Study models and specimens of the human vocal apparatus and the ear, noting the structures and functions of all of the parts. Make labeled DRAWINGS in order to understand and remember certain facts.

PLANT REACTIONS DUE TO HORMONES

Place a cutting or "slip" of silver-leaf geranium, willow, or similar plant in a test tube containing a weak aqueous solution of indole-butyric acid (commercially prepared organic growth substance related chemically to plant hormones). Place a similar cutting in a test tube containing distilled water. Why? Observe at intervals and explain any differences, especially in root formation.

The influence of small quantities of plant hormones, such as auxins, may be demonstrated by the following experiment with the tubular coleoptile (leaf sheath) of germinating oat plants (or similar grass seedlings). The coleoptile is the first part of the plant to emerge from the soil and completely covers the epicotyl (plumule), which consists of the growing stem and foliage leaves. The optimum temperature for auxin production in oat coleoptiles is about 25° C., if the relative humidity is high.

Remove part of the coleoptile from several seedlings by making a clean cut several millimeters below the tip. Contrast the future growths of such seedlings with those of similar plants from which the tips were not removed. Explain.

Remove the coleoptile tips as above and exchange them with each other by affixing them carefully on the remaining stumps. Observe the results and compare with similar plants on which coleoptile tips were not exchanged. Explain.

Place the cut end of several, similar coleoptile tips on thin layers (1 mm.) of a sterile 3% agar preparation for 1 hour. Remove the tips and cut the agar which contained the coleoptile tips into similar small blocks of equal size ($2 \times 2 \times 1$ mm.). Place one such block on the stump of each coleoptile being tested, and later observe if the agar has acquired hormone from the tip originally, and in turn transferred it to the stump. Place similar blocks of agar (without hormone) on similar coleoptile stumps as controls. Why? RECORD all results with proper explanations.

Remove the tips from several coleoptiles. Prepare auxin-containing agar blocks as above. Affix the auxin-containing block on each stump one-sidedly, so that the block does not completely cover it. Observe the results and explain them.

GERMINATION AND VIABILITY OF SEEDS

A simple way to test the viability of seeds (ability to grow when planted) is to use the reagent tetrazolium,* which is a vital stain (stains without killing). The reagent should be kept in the refrigerator. It is a so-called hydrogen acceptor in much the same way as the coenzyme DPN (diphosphopyridine nucleotide) and the cytochromes. By picking up two hydrogens from the Krebs cycle, it is reduced to a red color.

Three lots of corn kernels (corn kernels are fruits, not true seeds) are prepared as follows and labeled A, B, and C. One lot was left with normal germination ability. In another lot one-half of all of the seeds were killed by heating so that the germinating ability of the total lot should be reduced by approximately one-half from the normal. In still another lot three-fourths of all the seeds were heated so that germination ability of the total lot should be reduced by approximately three-fourths of the normal.

The viability of the three lots is to be tested as follows. Select 5 seeds from each lot and place in a small dish properly labeled. Cut the seeds longitudinally so as to bisect the internal embryo carefully. Pour just enough of the tetrazolium over the seeds to cover them. Observe in 30 to 60 minutes the viability of living tissues being demonstrated by a bright red color, whereas nonliving tissues are not so stained.

RECORD the number of seeds in each lot which show viability. Can you calculate the percentage viability of lots A, B, and C on the basis of your results? Would it be more desirable to use the results of the entire class? Why? In addition to the death

*See Appendix 3.

of the embryo, might loss of viability be due to a lack of stored food (starch)? Might it be due to one or the other, or to both?

To test for starch place a drop of iodine solution* on the cut surface of both viable and nonviable kernels which remain from the tetrazolium test. If starch is present, a bluish-black color develops. RECORD these results and add to your interpretation of the viability of the corn.

DRAW a sectioned corn kernel, showing the brilliantly colored red embryo and the dark endosperm. Magnify the section properly and identify and label all parts accurately.

PHENOMENA DUE TO ANIMAL ENZYMES

Numerous enzymes are produced by living protoplasm for a great variety of purposes. Each enzyme has a specific action, causing a specific chemical change upon one substrate (substance acted on). Enzymes are indispensable for the metabolic activities of living protoplasm. Some information concerning enzymes and their properties may be learned from studies of such common digestive enzymes as the following.

Change of starch to sugar by the digestive enzyme (ptyalin) of the saliva. In each of 4 clean test tubes place 5 ml. of 1% boiled starch, such as corn starch which has been filtered. (Prepare just before use.) Label the tubes 1, 2, 3, and 4. Secure saliva by chewing clean paraffin wax, and test with litmus paper (or similar testing paper) to determine if the saliva is alkaline, acid, or neutral. Add 10 ml. of saliva to tubes 1 and 2. Incubate tubes 1 and 3 at body temperature (37° C.) for 30 minutes. Allow tubes 2 and 4 to remain at a lower temperature.

While the tubes are incubating make the following practice tests.

1. To a few drops of the 1% boiled starch add a few drops of iodine solution.* A blue color indicates starch.

2. To a few drops of a solution of sugar, such as maltose (malt sugar) or glucose (grape sugar, dextrose), add a few drops of iodine solution. Does the sugar solution contain starch? Why are these preliminary control tests necessary?

3. To 5 ml. of a sugar solution add 2½ ml. of Benedict's reagent.* Boil and observe a greenish yellow precipitate which indicates sugar.

4. Boil Benedict's reagent alone to observe if it gives a test for sugar.

5. To 5 ml. of saliva add 2½ ml. of Benedict's reagent and boil to see if the saliva contains sugar.

6. To 5 ml. of the boiled starch add 2½ ml. of Benedict's reagent and boil to see if the starch contains sugar. Why perform each of these control tests?

After proper incubation test each of the four original tubes 1, 2, 3, and 4 for (a) starch and (b) sugar. In which tubes is sugar present? Explain the roles of the enzyme (ptyalin) and heat in this experiment. If starch is incompletely digested, the test with iodine solution may give a purplish color, indicating an intermediate product such as erythrodextrin.

Digestion of protein by the digestive enzyme (pepsin) of the stomach. Soak some fibrin (a protein) in distilled water and cut into pieces of equal size. Place a piece in each of 4 clean test tubes and label 1, 2, 3, and 4. In tube 1 place 20 ml. of distilled water. In tube 2 place 20 ml. of 0.1% solution of pepsin.* In tube 3 place 20 ml. of a 0.2% hydrochloric acid (HCl).* In tube 4 place 20 ml. of a 0.1% solution of pepsin in a 0.2% solution of HCl.

Mix the contents in all tubes and incubate all of them at body temperature (37° C.). Observe changes in the protein during the laboratory period, or next period if necessary. In which tube does digestion occur? Explain the roles of the enzyme pepsin and HCl. If desirable, repeat the experiment with a piece of boiled egg white one-half the size of a pea.

Digestion of fat by the digestive enzyme (lipase) of the pancreatic juice. Place 5 ml. of corn oil (or similar liquid fat) in each of 2 test tubes and label 1 and 2. Add 10 ml. of artificially prepared pancreatic juice* to each tube. Test with litmus paper

*See Appendix 3.

*See Appendix 3.

(or similar testing paper) to determine if alkaline, acid, or neutral. Why?

Incubate tube 1 at body temperature (37° C.) for 2 hours or more. Allow tube 2 to remain in a cooler place for the same period of time.

After the proper period of time observe the emulsion and the changed appearance due to the action of the lipase. Which tube shows digestion? Explain why. Explain the roles of the enzyme and heat.

Actions of additional enzymes. Various enzymes play important and specific roles in the protoplasm of living organisms from the simplest microscopic plants and animals to the highest types. Make such additional studies as suggested by the instructor. In each case RECORD your information under the following headings, (1) name of enzyme, (2) where enzyme is produced, (3) substance acted upon, (4) product produced by the specific enzyme, and (5) environmental conditions under which optimum action occurs.

BLOOD TYPING

A-B blood groups

When a foreign protein is injected into the blood stream of an animal, the cells of the animal produce a characteristic substance which will react with the foreign protein. The substance produced by the cells is known as an **antibody** (Gr. *anti,* against), and it becomes particularly abundant in the blood stream. A foreign protein which causes the formation of the antibody is known as an **antigen** (Gr. *anti,* against; *gen,* origin). Whenever an antigen and its antibody are brought together in solution, a typical **antigen-antibody reaction** occurs. Such reactions are of various types.

If the antigen is in the form of cells, the antibody formed (or already present) may react with it in such a way as to cause **agglutination (clumping)** of the cells. In this case the antigen is called an **agglutinogen** and the antibody an **agglutinin.**

Dr. Karl Landsteiner of Vienna (1900) discovered that when red blood corpuscles of one person were mixed with blood serum of certain other persons, agglutination of red blood corpuscles sometimes occurred. Normal antigens are present in the red blood corpuscles of some persons, and normal antibodies are present in the blood serums of some persons. There are 2 antigens (named A and B) in human red blood corpuscles and 2 corresponding antibodies (Anti-A and Anti-B) in human blood serums.

Whatever antigen a person has in his red blood corpuscles, the corresponding antibody is absent in his blood serum (or his blood corpuscles would agglutinate naturally and he would die). When a certain antigen is NOT present in his red blood corpuscles, the corresponding antibody IS present. This can be illustrated in Table 7.

Clean a glass slide thoroughly and blot dry. Mark it into halves with a glass marking pencil and label anti-A (upper left corner) and anti-B (upper right corner). Have your instructor place a single drop of anti-A blood serum in the appropriate half of the slide. Do likewise with a single drop of anti-B blood serum in the other half of the slide, and place the slide on white paper.

Sterilize your finger with alcohol and puncture the skin (near the nail) with a

Table 7. Antigens and antibodies of A-B blood groups

If blood contains agglutinogen (antigen) in red blood corpuscles	*If blood contains agglutinin (antibody) in blood serum*	*Blood will be agglutinated by serums with agglutinin*	*Blood group*
A	Anti-B	A*	A
B	Anti-A	B†	B
A, B	------	A and B‡	AB
----	Anti-A and anti-B	Not agglutinated	O

*Agglutinated but less strongly by serums containing both agglutinins, anti-A and anti-B.

†Agglutinated but less strongly by serums containing both agglutinins, anti-A and anti-B.

‡Agglutinated but less strongly by serums containing agglutinins, anti-A or anti-B.

Table 8. Summary of antigens and antibodies

Blood group	*Reactions with antiserums*	
	Anti-A	*Anti-B*
A	Agglutination	—
B	—	Agglutination
AB	Agglutination	Agglutination
O	—	—

sterile needle or lancet. Press out a drop of blood and with a clean toothpick transfer it to the drop of anti-A serum. Repeat the above, using a different clean toothpick and transfer the drop of blood to the anti-B serum. Why use a different toothpick? Keep the drops on the slide separate. Why? Rotate the slide carefully from side to side to mix your blood with the antiserums. WATCH CONTINUOUSLY and in a few seconds blood corpuscles will agglutinate (clump) in either, or both, or neither drops. Place a clean cover slip on each drop and examine microscopically.

RECORD the results and determine your blood type.

Rh blood factor

Clean a glass slide thoroughly and blot dry. Have the instructor place a drop of anti-Rh blood serum on the slide. Sterilize your finger with alcohol and prick (near the nail) with a sterile needle or lancet. With a clean toothpick place a drop of your blood on the slide, mixing it with the anti-Rh serum with the toothpick. Spread the mixture over an area of about 1 inch in diameter. Place the slide on a warming tray and tilt back and forth occasionally. The reaction should occur in 30 to 120 seconds. Read the results with the naked eye.

If the blood is Rh positive (Rh+), the blood corpuscles will appear in clumps (agglutinate), and the clumps will increase in size as time passes. If the blood is Rh negative (Rh−), there will be no agglutination and the mixture will appear homogeneous.

NOTE: It may be desirable not to rely too much on your results for blood typing, because you may have made errors, especially in interpretation.

IRRITABILITY, TRANSMISSION (CONDUCTION) OF EXCITATION, AND REACTIONS (BEHAVIORS) IN LIVING ORGANISMS

Responses in lower organisms

Behavior, or responses to stimuli, may be of various types and may be initiated by such stimuli as chemicals, light, heat, contact (touch), hormones, nerve impulses, etc. The degree of response may be influenced by the quantity and quality of the specific stimulus being observed, as well as the status of the organism at that time.

Place a cork in a glass tube (rather small caliber) and fill with a culture containing numerous **euglenae.** Cork the other end and cover one-half of the tube with black paper or cloth. Is their distribution affected by light? Were there any other factors which might have affected their distribution?

Repeat the experiment using paramecia, *Daphnia* (water flea), fruit flies *(Drosophila)*, or other animals. Explain each reaction to light.

Place a culture of living paramecia (or amebas) on a clean slide. Observe the effects when heat is applied to one end of the slide.

Prepare a slide containing a culture of paramecia (or amebas), and carefully apply a cover slip. Allow a solution of sodium chloride to flow under only one edge of the cover slip. Explain the results.

Repeat the above experiment, using weak acetic acid, and explain the results. What differences did you observe with the same types of animals when sodium chloride and acid were used? Explain these reactions.

Responses in higher plants

If not done previously, observe a sensitive plant *(Mimosa)* as you stimulate it in such ways as may be desirable (that is, heat, alcohol, chemicals, light with heat, light without heat, contact, etc.).

Observe the reactions in other plants such as (1) the growth of chlorophyll-bearing plants toward a source of light; (2) the twining of tendrils of certain plants around foreign objects; (3) the effects of light on the flowers of certain types of plants; (4) additional plants as supplied by the instructor. Explain the results observed in each case.

Behavior of a living crayfish

Place a living crayfish in water in an aquarium or large glass jar and study the external anatomy, particularly the many paired appendages. Observe specifically which appendages are used in walking and swimming. When frightened, which way does the crayfish move, forward or backward? In which direction is movement faster? Can you correlate this observed behavior with the natural living habits of the animal? What are the changes when it is removed from water? What is the method of righting itself when placed dorsal side down? Be specific in your answer. Which areas of the body are particularly sensitive to touch, light, chemicals, a magnet, sounds from a tuning fork, etc.?

Place several crayfishes in water in an aquarium or large glass jar. When they come in contact with each other, which body parts or appendages are used? Be specific in your answer. Does the behavior toward another animal seem "friendly" or "antagonistic"? Why do you say so? Can you relate this observed behavior with the natural living habits of the animal?

Observe the action of the gill bailer, an internal structure on the second maxilla (mouth part) which assists in the passage of water in the gill chamber (located beneath the chitinous exoskeleton). This can be done by placing a few drops of a carmine dye suspension (using a medicine dropper) under the anterior portion of the carapace (external chitinous covering of the body). Place the crayfish in the water in the aquarium which has a sheet of white paper beneath it. What is the direction of the jet of red material? How long does this expulsion occur? Does this seem like an efficient system? Why do you say so? Be sure to look at a demonstration specimen in which the gill bailer is attached to appendage No. IV (mouth part, known as the second maxilla).

How many different groups of paired appendages are there and how are the various groups constructed to do their specific functions? How efficient are the large pincers? You cannot be hurt if you handle a crayfish by picking it up just posterior to the large pincer. Test the reaction of the antennae and antennules. RECORD all the information which you have acquired.

TENACITY OF LIFE (SURVIVAL ABILITY OF PLANTS AND ANIMALS)

Place small amounts of (1) dried mud from a creek or pond bottom, and (2) frozen soil in separate aquaria or in similar glass dishes and partly fill with distilled water which has been sterilized. Why should the water be sterilized? Allow to stand in the laboratory and examine from time to time. If you find living organisms, what is their origin? Why do you say so?

ELECTROLYTIC DISSOCIATION

Protoplasm is a mixture of electrolytes, or substances which in solution are able to conduct electric currents and dissociate or ionize into positively charged ions and negatively charged ions. Electrolytes conduct electricity and, with the passage of a current through a solution, the positive ions move toward the cathode (negatively charged electrode) where they are reduced (gain electrons), whereas negative ions move to the anode (positive electrode) where they are oxidized (lose electrons).

If sodium chloride is dissolved in water, the positive sodium ions (Na^+) and the negative chlorine ions (Cl^-) are separated from each other by the water, and they exhibit the properties of free electrically charged units. If the two electrodes of an electric current (from a battery) are placed in such a solution, the positive ions will move to the cathode and the negative ions will move to the anode. When sodium chloride is electrolyzed in water, the reaction is written as follows:

$$2\,Na^+ + 2\,Cl^- + 2\,H_2O \xrightarrow{\text{Electric current}} Cl_2 + H_2 + 2\,Na^+ + 2\,OH^-$$

Make a DRAWING of an electrolytic apparatus, properly labeled. What has electrolytic dissociation to do with living protoplasm? Are there electric phenomena associated with certain phenomena in living organisms?

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Did you make all observations and interpretations accurately? List any instances where errors may have been made and why they were made.

6. Drawing logical conclusions based on data and facts obtained

RECORD the conclusions which you can draw from the logical interpretation of the data and information secured. List additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient evidence and are valid.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all instances where errors in observation or interpretation may have been made so that the information is as reliable as possible.

Part Five

THE CONTINUITY OF ORGANISMS ("PERPETUATION OF ORGANISMS")

43 Reproduction, embryonic development, and morphogenesis in plants and animals

1. Problems

PLANTS

Is there a continuity of protoplasm connecting individuals of successive generations through which hereditary traits have been transmitted from past generations and through which they will be transmitted from the present generation into the future? Do higher plants produce sex cells or gametes (gametogenesis) and spores (sporogenesis) for reproduction purposes? Do higher plants follow a definite life cycle in their embryonic development to maturity, and are these same stages in the life cycle repeated in the succeeding generations? Do higher plants produce a multicellular embryo from which a new individual is formed? Where is this embryo formed and how does it secure food for its development? Do true leaves and true roots develop from different parts of the embryo through a process known as morphogenesis? Does heredity play a role in determining the particular type of embryo which will develop in each species of plant? Does heredity play a role in determining the specific types of leaves, stems, roots, and flowers which will develop from the embryo? Do environmental factors influence embryonic developments in plants and, if so, what are some of the more common ones?

ANIMALS

Is there a continuity of protoplasm connecting individuals of successive generations through which hereditary traits have been transmitted from past generations and through which they will be transmitted from the present generation into the future? Do higher animals produce sex cells or gametes (gametogenesis) for reproduction purposes? Do higher animals follow a definite life cycle in their embryonic development to maturity, and are these same stages in the life cycle repeated in the succeeding generations? Do higher animals form a multicellular embryo from which a new adult is formed? Do comparative studies of the embryonic development of frog and man (study stages from slides, museum specimens, charts, models, etc.) reveal general similarities between the two, with certain differences to be expected? Do all tissues and organs in a triploblastic animal arise from three germ layers (ectoderm, mesoderm, and entoderm)? Does heredity play a role in determining the traits of the embryo and the adult which develops from it? Do many of the structures of the embryo develop as a result either of (1) invagination (growing inward) or (2) evagination (growing outward)? From what embryonic germ layer does a nervous system develop? Does a true body cavity (coelom) arise by a splitting of the mesoderm layer? Do the gills of a frog tadpole change in location and numbers in certain stages? Do the forebrain, midbrain, and hindbrain originate by developing from specific regions of the embryonic neural tube?

2. Preliminary observations and pertinent data and information

RECORD all the accurate and pertinent information which may be of value in the solution of the problems. Be certain that the information is true and actually pertains to the problems.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate, pertinent information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods of investigation which will supply additional pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Study charts and illustrations which show the continuity of protoplasm which explains how hereditary traits of a particular species are maintained in succeeding generations. Should this protoplasm really be called germ plasm?

PLANTS

Study charts, prepared slides, projected slides, illustrations, and museum preparations which show the production and maturation of sex cells, or **gametes (gametogenesis)**, and the production of **spores (sporogenesis)**, including the phenomenon of **reduction division (meiosis)** in which the number of chromosomes is reduced from the double or diploid (2N) number to the monoploid or haploid (N) number. Why must the number of chromosomes be reduced by one-half before a new plant is produced?

Study plant specimens, slides, museum specimens, charts, and illustrations, which show the **embryonic development (embryogenesis)** and **differentiation and development of tissues and organs (morphogenesis and organogenesis).**

Study charts, illustrations, projected slides, and museum specimens which show the **life cycle** of a typical angiospermous (flowering) plant.

DRAW a complete **life cycle** of a typical angiospermous plant, labeling each stage and all structures accurately. By means of arrows show the stages in correct sequence.

Embryonic development of angiospermous plants may be illustrated by studies of such representatives as the following.

Garden bean (Phaseolus). The embryonic development of seeds can be observed better if they have been soaked to initiate germination. Each bean is composed of (1) protective **seed coats;** (2) an **embryo** consisting of (a) fleshy halves known as **cotyledons,** which supply food for the developing embryo; (b) an **epicotyl (plumule),** which will develop **true leaves;** (c) a **radical,** which develops the **primary root;** (3) a small scar, the **hilum,** where the seed was attached to the bean pod; (4) a **raphe,** or ridge near the hilum; (5) the **micropyle,** or small opening near the hilum for the entrance of pollen for fertilization purposes.

DRAW a germinating bean, labeling all parts correctly.

Indian corn (Zea mays). The embryonic development can be observed better if the corn grain has been soaked to initiate germination. A corn grain consists of (1) a protective **seed coat;** (2) abundant **endosperm** (stored food), which nearly fills the space within the seed coat; (3) one **cotyledon** for supplying the embryo with the food; (4) an **epicotyl (plumule),** which develops **true leaves;** (5) **a radicle** (toward the tip of the grain), which develops the **primary root** of the seedling; (6) a sheathlike **coleoptile,** which encloses the young leaves and epicotyl; and (7) a sheathlike **coleorhiza,** which encloses the radicle.

DRAW a germinating corn grain, labeling all parts correctly.

ANIMALS

Embryonic development of the frog

Much valuable information concerning **embryonic development** can be secured by careful studies of slides, models, charts, museum preparations, lantern slides, film strips, movies, etc. Study each stage very carefully, noting the details as suggested below.

The embryonic developments of animals in general are similar, with minor differences at certain stages. Such development is illustrated by the frog because its stages are rather typical, representative, rather easily obtained, and are not expensive.

The sexes of the frog are separate (dioecious). The **sperms** produced by the testes of one frog unite with the **eggs** produced by the ovaries of another frog. This union results in a **zygote,** or fertilized egg. The eggs are jellylike and are often found in fresh water during early spring. Each egg is about the size of a buckshot and has several **concentric** layers of jellylike material known as the **vitelline membrane.** Study such an egg.

Two or three hours after fertilization the zygote divides to form a **2-cell stage,** the two remaining in contact. A second division occurs in about one hour and at right angles to the first plane of division, thus forming a **4-cell stage.** Each of these cells is known as a **blastomere.** Study such a stage.

The next plane of division occurs slightly above the middle, or equator, thus transversely dividing the four cells to form an **8-cell stage.** Four of these cells are smaller, pigmented, and known as **micromeres;** the other four are larger, unpigmented, and are known as **macromeres.** The micromeres are located at the **animal pole** and the macromeres at the **vegetal pole.** Study such a stage.

The eight cells divide to form a rather compact mass of cells known as the **morula stage.**

The **micromeres** divide more rapidly than the **macromeres** at this time. Study such a stage.

Eventually, the cells of the morula arrange themselves in a very definite manner to form a spherical structure known as the **blastula.** The blastula is made of only one layer of cells (the cells of the original morula). The hollow, internal cavity of the blastula is known as the **blastocoel.** The entire blastula is covered with a transparent jellylike **capsule.** There are two groups of dissimilar cells in the blastula: a light-colored, unpigmented **vegetal hemisphere** which floats downward and a dark, pigmented **animal hemisphere** composed of smaller and more numerous cells (**ectoderm**). The vegetal cells are large and contain **yolk** (food). Active growth occurs principally in the animal hemisphere in this stage. Study such a stage carefully.

In the **gastrula stage (yolk plug stage)** at a certain point between the animal and vegetal hemispheres, the vegetal cells grow inwardly into the blastocoel. The pigmented animal cells (ectoderm) grow over the lighter colored vegetal cells (entoderm) and fold in with them slightly at that point. Because of more rapid divisions, the animal cells grow almost entirely over the vegetal, leaving a small, light **yolk plug** exposed. The space between the boundaries of the infolded layers of cells and that which surrounds the yolk plug is the **blastopore (primitive mouth).** The latter is shown on the surface by a crescent-shaped fold or groove. The outer layer of cells (**ectoderm**) is continuous with the inner, inturned layer (**entoderm**). This entoderm eventually forms the **archenteron** (primitive intestine or gut) in the blastocoel. During this stage the blastocoel is being reduced in size. Study such a stage very carefully, noting all the structures mentioned.

In the **neural groove stage** the neural groove, which is the forerunner of the future nervous system, begins as a small depression on the dorsal side. The groove grows along the dorsal side of the embryo as a thickened **neural plate** (medullary plate) in the ectoderm. During this period the embryo is elongating with definite **anterior** and **posterior ends.** The thickened fold at each margin of the original neural plate forms the **neural fold** (medullary fold). These folds at first are flat and far apart, but later they arch toward the median, dorsal line and unite to form the future **neural tube.** The neural plate now sinks to form a definite **neural groove** along the mid-dorsal side of the embryo.

An elongated mass of cells dorsal to the archenteron forms the **notochord.** The notochord eventually develops into the segmented **vertebral column.** The mass of cells at either side of the neural groove is known as the **mesoderm** (middle germ layer). Study a neural groove stage carefully.

In the **neural tube stage** the tube will eventually free itself from the outer ectoderm from which it originated. The anterior part of the neural tube constricts to form the future **forebrain, midbrain,** and **hindbrain.** The **notochord** is now free from the archenteron and is just below the neural tube. Study this stage.

The mesoderm eventually splits into two layers with a cavity, the **coelom** (body cavity), between them. The inner layer next to the entoderm is known as the **splanchnic layer,** and the outer next to the ectoderm is the **somatic layer.** Study these structures.

About this time the embryo is known as a **larva,** with **external gills** and a pair of oval, thick-lipped **suckers** for attachment. The **stomodeum** (primitive mouth) is an oval pit in front of the suckers. A pair of small **olfactory pits** are above and anterior to the stomodeum. Three pairs of **external gills** on the sides of the head act as respiratory organs. The **proctodeum** (anal opening) is on the dorso-posterior part of the embryo or tadpole. A **tail** and a pair of **eyes** are also present. Study this stage, noting all structures carefully.

The external gills are eventually covered by a fold of skin known as the **operculum** (gill cover), with a single opening called the **spiracle.** As the three pairs of external gills are absorbed, four pairs of **internal gills** are formed. The **mouth** is surrounded by a number of small projections known as **circumoral papillae** and contains a pair of horny **jaws.** Note the long, coiled **intestine** visible through the ventral body wall. Observe the **hind limb buds** near the proctodeum.

In still later stages the **front limb buds** appear. The limb buds develop into true limbs. The tail is gradually resorbed, the materials being stored in the liver. The internal gills are resorbed and give way to the pair of **lungs** of the adult frog. The coiled intestine becomes shorter, thus suggesting the carnivorous nature of the adult frog.

Make correctly labeled DRAWINGS of all of the above stages.

In order to secure comparable information concerning the embryonic development of other vertebrates study living specimens, or prepared demonstration slides, of a 72-hour or 96-hour chick embryo, noting all structures which are formed at this stage. Other stages of the chick or other vertebrate embryos may be studied or demonstrated, as time permits.

In order to secure comparable information concerning the later stages of human embryonic development, study such materials as are available, noting similarities and differences when other embryos are considered.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently detailed and extensive to provide additional pertinent information? Why do you say so? If you think that you made errors, give reasons why they were made. Suggest specific ways by which accurate, additional information might be secured.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they justified and valid as based on the available information? RECORD additional conclusions which may not be associated directly with the problems. Do you feel that you are rather familiar with the embryonic development of vertebrates as revealed by your studies?

Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations, especially those with which you may have had difficulties. Did you repeat your observations sufficiently to guarantee accuracy? If you did not, why not?

Reproduction, embryonic development, and morphogenesis in animals

Homology as shown by segmental appendages of crayfish

1. Problems

Do the segmental appendages of such an animal as the crayfish illustrate the principle of homology, in which the homologous structures develop from basically similar embryonic structures and are usually fundamentally similar in structure (in the adult)? Do the serially homologous appendages of the adult crayfish have different functions?

2. Preliminary observations and pertinent data and information

RECORD any accurate information which you may have concerning the appendages of the crayfish and which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From your accurate information which pertains to the problems formulate hypotheses from which you may work toward their solution. RECORD methods of investigation which will supply additional pertinent information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

The principle of homology may be illustrated by a careful study of the series of segmental appendages of such animals as crayfish, insects, etc. Remove each appendage from a crayfish in proper sequence, starting with the last, or XVIII, and removing each in proper sequence until number I is reached. They are more easily removed by following this procedure. (Studies may be made of properly labeled appendages which have been removed previously and stored in bottles.)

Study each appendage carefully, noting especially such parts as the protopodite, the endopodite, and exopodite. Note the functions of each. Study a table of these appendages and record the detailed information on accompanying pages.

Make correctly labeled DRAWINGS of such appendages as suggested in order to remember certain facts.

If desirable, study demonstration slides showing the similarity in embryonic origin of the serial, segmental appendages of the crayfish. Do such embryonic appendages appear to be similar? Is this evidence of homology?

If desirable, make a labeled DRAWING of the embryonic crayfish appendages.

Examples of homology in the animal kingdom include the forelimbs of the horse, cow, dog, cat, the wings of bats and birds, and the arm of man. Homology is shown by a detailed bone-by-bone study of the skeletons of such animals as the frog, turtle, bird, and mammals, including man. The digestive, excretory, muscular, and skeletal systems of such animals show a certain degree of homology, although a certain amount of variation among them is to be expected. The budlike outgrowths (limb buds) in early embryos also show this similarity.

Study such additional illustrative materials as suggested and make labeled DRAWINGS, if time permits.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove your hypotheses and the problems? Were your studies sufficiently extensive and accurately made so that additional, pertinent information was secured? Why do you say so? If you think that you made errors, give reasons why they were made. Suggest specific ways by which accurate, additional information might be secured.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the available information? Record additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure accurate, pertinent information. Repeat all observations and interpretations, especially those with which you may have had difficulties. Were your observations repeated a sufficient number of times to guarantee accuracy?

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HOMOLOGY AS SHOWN BY THE SEGMENTAL APPENDAGES OF A CRAYFISH

Appendage	Protopodite	Endopodite	Exopodite	Functions
(On Cephalothorax) (12 segments) I. Antenna				
II. Mandible				
III. First maxilla				
IV. Second maxilla				
V. First maxilliped				
VI. Second maxilliped				
VII. Third maxilliped				
VIII. First walking leg (pincer or cheliped)				
IX. Second walking leg				
X. Third walking leg				
XI. Fourth walking leg				

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HOMOLOGY OF SEGMENTAL APPENDAGES OF A CRAYFISH (CONCLUDED)

Appendage	Protopodite	Endopodite	Exopodite	Functions
XII. Fifth walking leg				
(On abdomen) (6 segments) XIII. First abdominal (swimmeret, or pleopod)				
XIV. Second abdominal (swimmeret, or pleopod)				
XV. Third abdominal				
XVI. Fourth abdominal				
XVII. Fifth abdominal				
XVIII. Sixth abdominal (uropod)				

Genetics (heredity) and variations in plants and animals

1. Problems

How are certain heritable traits of plants and animals transmitted from generation to generation? What roles do chromosomes and their genes play in the transmission and development of heritable traits? What contribution did Gregor Mendel make to experimental genetics? Do the visible traits displayed by an organism always tell the true genic content, especially if the organism is heterozygous for that trait? Can two parents, which are both heterozygous for a certain trait, produce offspring which show the recessive trait? Do body cells possess the diploid (2 N) number of chromosomes and genes, whereas the gametes (sex cells) possess the monoploid or haploid (N) number? In sexual reproduction does each parent contribute one gene for each trait, and may these genes be alike or different? If the genic content of parents is known, can the ratios of traits be determined in their offspring? If the hereditary ratios of traits in a sufficiently large number of offspring are known, can the genic content of the parents which necessarily produced them be ascertained? Of what importance are phenotype and genotype ratios? Can these ratios be determined as shown by checkerboards (on accompanying pages)? Which of Mendel's laws are illustrated by the inheritance of certain traits in garden peas, guinea pigs, and fruit flies (on accompanying pages)? Are the phenotype and genotype ratios in a dihybrid cross (2 traits) in an organism different from those ratios in a trihybrid cross (3 traits) in the same organism? Do all living organisms vary either through their inheritance, through environmental influences, or through a combination of the two? What determines whether a variation is beneficial, detrimental, or neither?

2. Preliminary observations and pertinent data and information

RECORD all information pertinent to the problems as accurately as possible. Be certain that your information is accurate.

3. Formulation of hypotheses and determination of methods of investigation

From the pertinent and reliable information formulate hypotheses from which you may work toward the solution of the problems. RECORD specific methods which may be followed for securing additional, reliable information.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent information

Study prepared slides (or demonstration slides) of cells which show **chromosomes** and attempt to observe as many details as possible. Study charts and illustrations of chromosomes showing detailed structures.

GENETICS IN PLANTS (GARDEN PEAS AND INDIAN CORN)

Previous to the production of offspring by two parents, there must be a **segregation and an independent assortment of the**

chromosomes and their genes. By chance one of each pair of genes may go to one offspring and the other one of each pair may go to another offspring. The ratio when only one pair of genes is studied will be different from the ratio when two pairs of genes are studied simultaneously. This may be illustrated by tossing coins. Designate each coin head (H) and tail (h). Students may work in pairs in these procedures.

1. Toss a coin 10 times and RECORD your results as to the ratio of H : h. RECORD results for the entire class. Are there differences between your results and those of the entire class? Explain.

2. Toss 2 coins (of same kind) simultaneously 20 times and RECORD your results as HH : Hh : hh. RECORD the results for the entire class. Explain any differences.

3. Select 4 coins (2 each of 2 different kinds) designating each side of each coin by a proper symbol (that is, penny head [P] and penny tail [p]; nickel head [N] and nickel tail [n]). Toss the 4 coins simultaneously 20 times and RECORD accurately the number of times each of the various combinations occur, as follows:

PPNN : PPNn : PPnn : PpNN : PpNn : Ppnn : ppNN : ppNn : ppnn

RECORD these results for the entire class and explain differences between your results and those for the entire class. Do these ratios approximate the theoretical ratios? Why or why not?

Study museum preparations (as suggested by the instructor) of **monohybrid crosses of garden peas,** such as those studied by Gregor Mendel and from which he formulated his laws. Observe the ratio of the traits being studied.

Study museum preparations of **dihybrid crosses of garden peas,** noting the ratios of inheritance of the traits studied.

With characteristics and symbols for the parents (P) supplied by the instructor, complete the exercise on a **dihybrid cross of garden peas** (on an accompanying page). RECORD both phenotype and genotype ratios which you ascertain from the F_2 (second filial) generation.

Study museum preparations of other plants (such as colors, starch or sugar content of kernels of Indian corn) which show monohybrid crosses and dihybrid crosses, noting carefully the specific ratios in each specimen. Make accurate counts.

Study such additional materials as supplied by the instructor which show various genetic phenomena in plants.

STATE each of Mendel's laws which are illustrated by your studies.

An interesting genetic phenomenon showing **lethal (killing) genes** may be demonstrated by growing special hybrid **seeds of sorghum** (tobacco or other plant). Proper hybrid seeds for growing green and albino (white) seedlings will show segregation and a 3 : 1 ratio in the F_2 generation.

The hybrid sorghum seeds are planted in clean garden soil or sand and covered to a depth of one inch. Twenty seeds which have been presoaked should be planted in each pot of sufficient size to prevent crowding. The pots are placed in a warm, well-lighted place and the soil kept moist. White (nonchlorophyll-bearing) seedlings will die in 3 to 4 weeks when the food supply of the seed is exhausted. RECORD the ratio between normal and lethal seedlings. Did all 20 seeds germinate? Would the results taken from many pots be more reliable than those from one pot? Why?

GENETICS IN ANIMALS (GUINEA PIGS AND FRUIT FLIES)

Trihybrid cross (guinea pigs)

The inheritance of traits in animals may be illustrated by a **trihybrid cross** in such an animal as the **guinea pig.** The characteristics and symbols for the parents (P) for such a cross will be given by the instructor and they should be placed in the proper blank spaces on the accompanying page. From these work out the correct gametes (sex cells) for each parent and record properly. By selecting one gamete from each parent and combining them RECORD the characteristics and symbols for the offspring of the F_1 generation. Next determine the gametes produced by the F_1 offspring. Place this group of gametes along the upper side of the checkerboard and call them male gametes. Place the same group of gametes along the left side of the

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DIHYBRID CROSS (PEAS)

	Male		Female
Parents (P) — Characteristics ___	(	) X (	)
Symbols ___	(	) (	)
Gametes produced by (P)	(	) (	)
F_1 generation — Characteristics	(		)
Symbols ___	(		)
Gametes produced by F_1 ___	(		)

F_2 generation ___

Male gametes

Female gametes

KEY:

T-tall plant
t -short plant
R-round seed
r -wrinkled seed

PHENOTYPE RATIO: ______________________

GENOTYPE RATIO: ______________________

(From the F_2 generation)

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TRIHYBRID CROSS (GUINEA PIGS)

	Male		Female
Parents (P) — Characteristics	( )	X	( )
Symbols ________	( )		( )
Gametes produced by (P) ________	( )		( )

F_1 generation-Characteristics ____________ ( )

Symbols ____________ ( )

Gametes produced by F_1 ____________ ( )

F_2 generation —

Male gametes

Female gametes

KEY:

B-black hair

b-white hair

R-rough hair

r-smooth hair

S-short hair

s-long hair

PHENOTYPE RATIO: ____________________

GENOTYPE RATIO: ____________________
(From the F_2 generation)

checkerboard and call them female gametes. When all of the male gamete possibilities are combined with all of the female gamete possibilities, we have the F_2 generation. From all of the squares in the checkerboard ascertain the phenotype and genotype ratios for such a trihybrid cross and record on the accompanying page.

Crosses in fruit flies

Another way to prove some of the laws of heredity is to cross experimentally living **fruit flies** *(Drosophila* sp.) possessing certain specific traits and observe the inheritance of these traits in successive generations. If we use as parents (P) a male fly with vestigial wings (ll) and a female with normal wings (long wings) (LL) and cross them, all offspring of the first filial generation (F_1) will inherit either normal or vestigial wings, depending on which is dominant.

The technique for making such a cross is as follows. Flies are reared in culture bottles containing a special medium.* For this experiment males with their specific hereditary traits are kept in one bottle and females with their traits in a separate bottle.

Jar the bottle which contains the male flies by striking sharply to shake them to the bottom. A piece of cotton moistened with ether is placed in a similar bottle (without medium). Remove the stoppers and place the open ends of the two bottles together. Do not allow the flies to remain in the ether vapor for more than 10 to 20 seconds after they cease moving. (They may be given another etherization if they move during the observations.) Place several flies on white paper to identify the sex. Male fruit flies usually are smaller than females and the tip of the abdomen is black, whereas females have the tip of the abdomen striped. Place 4 males in a new bottle containing the culture medium. Following the same procedure place 4 females in the new bottle with the males. Be careful that the flies are not killed by adhering to the surface of the medium. Label the new culture bottle and record the traits of the parents (P) (both sexes) being used, your name, and date. Place the bottle in a place designated by the instructor.

In 6 days, when pupae appear, remove all parent flies. When new adult flies have developed from the pupae, count the F_1 generation. Which trait is dominant? What is the genic content of these F_1 flies?

At this time prepare an F_2 generation by putting 4 F_1 males and 4 F_1 females together in a fresh bottle of medium. Repeat the procedures described above and make counts for the trait being observed. Theoretically what should the ratio be? What ratio do you get by careful, actual count?

An interesting demonstration of a genetic trait in man may be illustrated by the use of strips of paper impregnated with **PTC (phenyl-thio-carbamide).*** Each student will place a strip of this paper in his mouth and RECORD if it tastes bitter, or if there is no taste. Some persons do not taste the chemical substance in the concentration used while others do, which suggests a variation in the method of inheritance from a simple dominance-recessive type. Similar pieces of paper should be used to test the parents, grandparents, brothers, sisters, etc. This may be done during a vacation period when at home, or the papers might be sent home in clean envelopes with proper directions for their use and accurate records. RECORD the traits for your entire family in the form of a family tree to show the presence or absence in each individual. Theoretically, in a large group of persons there are about ¾ tasters to ¼ nontasters.

VARIATIONS IN PLANTS AND ANIMALS

One of the characteristics of living organisms is their ability to vary. Even though two organisms may seem alike, each may vary more or less from the other. Variations in organisms may arise because of their specific inheritance, environmental influences, or a combination of the two.

With a metric ruler measure accurately 100 beans (or similar materials), measuring to the nearest millimeter (do not use fractions). RECORD the number of individuals in each category. Place the various

*See Appendix 3.

*See Appendix 3.

lengths which you have determined in a graded series from the smallest to the largest. Make a CHART showing the variations in size with the total numbers of each size by means of a CURVE. What is the average size of the 100 beans? How many individuals fall in this category? What is the smallest size and how many individuals are in this group? What is the largest size and how many individuals are in this group? What explanations can you give for such variations? Are these variations due to heredity, to environmental causes, or to a combination of the two? Explain your conclusion and give proof for your answer.

Measure accurately the **lengths (or widths) of the leaves** on a certain plant. Make a CHART and plot a CURVE as suggested above. What are the explanations for such variations? Are all the leaves of the same age? Does this factor make a difference?

With a metric ruler measure accurately **100 snail shells** (or other animal materials), measuring to the nearest millimeter and not using fractions. RECORD the number of individuals in each category (length). Place the various lengths which you have determined in a graded series from the smallest to the largest. Make a CHART showing the variations in size with the total numbers of each size by means of a CURVE. (Place on a separate page with proper labels.) What is the average size of the 100 snails? How many individuals fall into this category? What is the smallest size and how many individuals are in this group? What is the largest size and how many individuals are in this group? If these snails had the same inheritance, theoretically, what explanations can you offer for these variations?

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? State specifically why you say so. Did you make all observations and interpretations accurately and carefully? List any instances where errors may have been made.

6. Drawing logical conclusions based on data and facts obtained

RECORD the conclusions which you can draw from the logical interpretation of the information which you secured. Do your conclusions prove or disprove the hypotheses? List additional conclusions which you can draw from your studies which may not be directly connected with the problems as stated. Are your conclusions valid and why do you say so?

7. Rechecking all steps

Recheck all information to ascertain if it is accurate and that you made the proper interpretation in each instance. Recheck any instances where you may have made errors in observation or interpretation, and reconsider your conclusions in the light of the newly evaluated information. If time permits, make additional studies which might provide additional, pertinent information.

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Special problems in genetics

AMONG THE VARIOUS TYPES of heredity we shall consider (1) sex-linked traits, (2) lethal genes, and (3) multiple alleles. The solution of certain problems may assist in understanding these methods of inheritance.

Sex-linked traits (**genes**) are those which are carried on the sex chromosome (X); thus the inheritance of such a trait will vary between the sexes.

Lethal genes produce fatal results regularly and have been found in most kinds of plants and animals. Some lethal genes are completely recessive producing no discernible effect in the heterozygote but killing the animal or plant that has them in the homozygous condition. Other lethals, besides being fatal when homozygous, have recognizable but nonlethal effects in the heterozygotes. If genes of the latter type kill before birth or hatching (or before germination in plants), they result in a modification of the 3 : 1, or 1 : 2 : 1 ratios. An example of a modified 3 : 1 ratio by a gene which produces a conspicuous effect in the heterozygote and when homozygous kills during embryonic development is shown by the so-called Creeper fowl (a chicken with legs and wings considerably shortened and deformed, thus producing a squatty appearance).

The term allele applies to the members of a pair of contrasting genes, and the two alleles of a pair segregate (separate) at reduction division, with the result that each gamete (sex cell) contains only one allele of each pair. A gene occupies a particular spot, or locus, on a chromosome, so that a chromosome could contain one or the other of a pair of alleles but normally not both.

However, certain sets of alleles contain more than two members. Some sets, called **multiple alleles,** contain from 3 to 20 or more members. No matter how many members a set of alleles may contain, only two of them may occur normally in any body (somatic) cell and only one of them in a gamete.

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I. SEX-LINKED TRAITS

In these problems dealing with sex-linked traits the sex chromosomes are X chromosome (X) and Y chromosome (Y).

A. Eye colors of the fruit fly (Drosophila)

(1a) If a red-eyed male is crossed with a white-eyed female, what are the eye colors of the F_1 males and females?

KEY:

R—red eye color

r—white eye color

(carried on X chromosome)

Parents	(XY) ( ) (Red, male)	X	(XX) ( ) (White, female)
F_1	(XY) ( ) (White, male)		(XX) ( ) (Red, female)

(1b) If an F_1 female from 1a, above, is crossed with her father, what are the eye colors of the offspring?

Parents	(XX) ( ) (Red, female)	X	(XY) ( ) (Red, male)	
F_1	(XY) ( ) (Red, male)	(XY) ( ) (White, male)	(XX) ( ) (Red, female)	(XX) ( ) (Red, female)

(1c) What are the eye colors of the offspring when a F_1 male from 1a, above, is crossed with his mother?

Parents	(XY) ( ) (White, male)	X	(XX) ( ) (White, female)
F_1	(XX) ( ) (White, female)		(XY) ( ) (White, male)

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(2a) If a homozygous red-eyed female is crossed with a white-eyed male, what are the eye colors of the F_1 males and females?

Parents (XX) X (XY)
( ) ( )
(Red, female) (White, male)

F_1 (XY) (XX)
( ) ( )
(Red, male) (Red, female)

(2b) What are the eye colors of the offspring when a F_1 female from 2a, above, is crossed with her father?

Parents (XX) X (XY)
( ) ( )
(Red, female) (White, male)

F_1 (XX) (XX) (XY) (XY)
( ) ( ) ( ) ( )
(Red, female) (White, female) (Red, male) (White, male)

(2c) What are the eye colors of the offspring when a F_1 male from 2a, above, is crossed with his mother?

Parents (XY) X (XX)
( ) ( )
(Red, male) (Red, female)

F_1 (XY) (XX)
( ) ( )
(Red, male) (Red, female)

B. Hair colors in cats (sex-linked)

(1a) If a tortoise-shell female is crossed with a black male, what are the colors in the offspring? What is the sex of the tortoise-shell kitten? Why? What is the probability of having a black male? A black female?

KEY:
B—yellow color
b—black color
Bb—tortoise-shell color (incomplete dominance)

Parents (XX) X (XY)
( ) ( )
(Tortoise-shell, female) (Black, male)

F_1 (XY) (XY) (XX) (XX)
( ) ( ) ( ) ( )
(Yellow, male) (Black, male) (Tortoise-shell, female) (Black, female)

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C. Human color-blindness (sex-linked)

(1) A girl with normal vision, whose father is color-blind, marries a man with normal vision but whose father is color-blind. What types of visions can be expected in the offspring? Why?

Parents (XY) X (XX) (XY) X (XX) KEY:

( ) ( ) ( ) ( ) C—normal vision

(Color-blind, male) (Normal, female) (Color-blind, male) (Normal, female) c—color-blindness

F_1 (XX) X (XY)

( ) ( )

(Normal, female) (Normal, male)

(XY) (XY) (XX) (XX)

( ) ( ) ( ) ( )

F_2 (Normal, male) (Color-blind, male) (Normal, female) (Normal, female)

(2) A man and a woman, both with normal vision have (a) a color-blind son who has a daughter with normal vision; (b) a daughter with normal vision who has one son who is color-blind and one son who has normal vision; and (c) another daughter with normal vision who has six sons all with normal vision. What are the probable genotypes of each person? Why?

Parents (XY) X (XX)

( ) ( )

(Normal, male) (Normal, female)

F_1 (XY) X (XX) (XX) X (XY) (XX) X (XY)

( ) ( ) ( ) ( ) ( ) ( )

(Color-blind, male) (Normal, female) (Normal, female) (?) (Normal, female) (?)

F_2 (XX) (XY) (XY) (XY)

( ) ( ) ( ) ( )

(Normal, female) (Color-blind, male) (Normal, male) (Six normal, males)

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II. LETHAL GENES

A. Poultry

(1) In a cross of chickens with both parents being creepers (short-legged), the offspring were approximately 2,000 creeper and approximately 1,000 normal (2:1). Explain why the ratio is 2:1 and give the genotypes of all chickens involved.

Parents	( ) (Creeper)	X	( ) (Creeper)	KEY: CC—creeper (dies); Cc—creeper; cc—normal
F_1	( ) (2,000 Creepers)		( ) (1,000 normals)	

Explain the difference between homozygous and heterozygous Creepers.

(2) In another cross when one parent was creeper and the other was normal, the offspring were approximately 1,500 creeper and approximately 1,500 normal (1:1). Explain why the ratio is 1:1 and give the genotypes of all chickens involved.

Parents	( ) (Creeper)	X	( ) (Normal)
F_1	( ) (1,500 Creepers)		( ) (1,500 Normals)

III. MULTIPLE ALLELES

A. Hair color in rabbits

(1) The multiple gene type of inheritance may be illustrated by studies of the hair colors of rabbits. The sequence of dominance is given in the Key, from full color to albino. Explain the genotype for each rabbit in the following crosses:

(a) Parents (   ) (Full color, homozygous) X (   ) (Chinchilla, homozygous)

F_1 (   ) (Full color)

KEY:
C—full color
c^{ch}—chinchilla (silvery gray appearance)
c^{h}—Himalayan albino (white body hair with pigmented nose, ears, tips of feet, tip of tail)
c—albino

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(b) Parents ( ) X ( )
(Full color, homozygous) | (Himalayan, homozygous)

F_1 ( )
(Full color)

(c) Parents ( ) X ( )
(Chinchilla, homozygous) | (Himalayan, homozygous)

F_1 ( )
(Chinchilla)

(d) Parents ( ) X ( )
(Chinchilla, homozygous) | (Albino)

F_1 ( )
(Chinchilla)

(e) Parents (C c^h) X (C c^h)
(Full color) | (Full color)

F_1 ( ) ( ) ( ) ( )
(Colored) (Colored) (Colored) (Himalayan)

(f) Parents (C c^h) X (c^h c)
(Full color) | (Himalayan)

F_1 ( ) ( ) ( ) ( )
(Full color) (Full color) (Himalayan) (Himalayan)

B. Human blood groups

(1) The inheritance of human blood groups (types), such as A, B, AB, and O, is determined by multiple genes. I^A and I^B are each dominant to i, but neither is dominant to the other. Explain the genotypes for each person in the following crosses:

(a) Parents ( ) X ( )
(Type A) | (Type B)

F_1 ( ) ( ) ( ) ( )
(Type A) (Type B) (Type AB) (Type O)

KEY:

Blood group	Genotypes
A	I^AI^A, or I^Ai
B	I^BI^B, or I^Bi
AB	I^AI^B
O	ii

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(b) Parents ( ) X ( )

(Type A) | (Type A)

F_1 ( ) ( ) ( ) ( )

(Type A) (Type A) (Type A) (Type O)

(c) Parents ( ) X ( )

(Type AB) | (Type B)

F_1 ( ) ( ) ( ) ( )

(Type A) (Type B) (Type B) (Type AB)

(2) In the following cases of disputed parentage, determine the probable father of the child.

(a) The mother belongs to group B, the child to AB. Which of the men, (A) or (B), could be the father? List the genotype for each person.

Parents (, or) X ( ) X (, or)

(Man, type A) (Mother, type B) (Man, type B)

F_1 ( )

(Type AB)

(b) The mother belongs to group B, the child to group O. Which of the men, (A) or (AB), could be the father? List the genotype for each person.

Parents ( ) X ( ) X ( )

(Man, type A) (Mother, type B) (Man, type AB)

( )

F_1 (Type O)

Family traits—a study of your family

WRITE a REPORT based on the inheritance of certain traits through several successive generations of your family. Include in your report the title of the report; its purpose; sources and methods of securing reliable, pertinent data; conclusions; and a bibliography of references used. In collecting data be accurate and truthful in all of the observations and interpretations. If your own family and ancestors cannot be studied, substitute another family with its ancestors about whom you can get accurate and detailed information.

Study your complete family (all members) for as many successive generations as possible. The omission of one member or the wrong interpretation of the presence or absence of the trait may result in incorrect conclusions. Select several traits which seem to characterize the family. Some suggested traits include: curly hair vs. straight hair; dark hair vs. light hair; nonred hair vs. red hair; long eyelashes vs. short eyelashes; dark skin color vs. light skin color; free ear lobes vs. attached ear lobes, etc. Trace the traits through all individuals of as many generations as possible. **Be accurate and truthful.**

To assist in this part of the work it is desirable to list all members of the family and their ancestors on "both sides of the house." Now list the trait which you have selected as being present or absent in each individual. Bear in mind that a trait need not be present in all individuals. **Do not guess at the trait** but check each member, recording whether it is present or absent.

Make a **family pedigree chart** showing all members of the family, including all ancestors. If necessary, place your chart on several sheets of paper (8½ × 11) which are pasted together and folded so as to fit in a large notebook (do not use large cardboard). In recording the data on a particular trait it is necessary to use certain **standardized symbols,** some of which are as follows: (1) males as squares; (2) females as circles; (3) individuals with sex unknown as diamonds; (4) children, the number and sex unknown, an **X**; (5) twins, ○̂○; (6) died in infancy, "d. inf."; (7) marriage, horizontal lines between the middle of the proper square and the middle of the proper circle; (8) offspring line, a vertical line which extends downward from the marriage line; (9) for various members of the immediate group of offspring (brothers and sisters), a line at right angles to the lower end of the offspring line; (10) for various individual offspring, proper squares and circles at the lower ends of vertical lines which extend downward from the line mentioned immediately above; (11) the various generations, Roman figures as I, II, III on the left margin of the chart; (12) various individuals of each generation, **Arabic figures** as 1, 2, 3, 4, 5, etc., reading from left to right.

After you have prepared a piece of paper large enough, make the CHART showing each individual in proper position. Place at the top of the chart the name of the trait being studied. Indicate the presence of the trait (preferably the dominant one) by a solid colored square or circle as the case may be, and represent the absence of that trait by empty squares and circles. Place a ? in a square or circle for which the information was not easily determined. If the data for the trait are not available for individuals place in the proper square or circle a U (unobserved). Why is this important?

Make a separate CHART for each additional trait studied.

Questions and topics

Does the trait seem to be inherited as shown by your family? Does it appear to be dominant or recessive? Do both parents contribute their genes (through gametes) to the zygote (fertilized egg), which transmits them through successive cell divisions during the entire life of the individual? Is the problem of studying human heredity quite difficult because of (1) the comparatively long period of time to reach maturity (time between successive generations); (2) the relatively small number of offspring produced; and (3) the difficulty of experimentally crossing human beings as can be done in lower animals and plants? Is the use of a Family Pedigree Chart a useful method of studying human heredity? What laws of heredity are illustrated by the chart which you constructed?

Living organisms—their origins, continuity, and evolution

WERE THERE EARLY THEORIES that living organisms arose spontaneously from non-living materials? How were they disproved scientifically? Do embryonic studies reveal that the life of each individual organism arises from pre-existing life, and that an individual organism is merely one link in the endless chain extending from the distant past into the future? Does each living organism go through a definite series of stages of embryonic development from the zygote (fertilized egg) to the adult? Is the time schedule for the appearance of specific tissues, organs, and systems sufficiently accurate so that the age of the embryo may be approximated by the appearance of them? In general do the various earlier stages of the embryos of closely related forms resemble each other, thus making it difficult to distinguish one from another? Do the various stages which certain embryos undergo resemble in a general way the history of development of that race? Just as we observe changes in the stages of embryonic development of individual organisms, does there seem to have been an evolution (descent with change) as the ancestral development of the race is traced through its successive generations? Does the development of organisms depend on their inheritance and the effects of external and internal environmental influences? Do the stages of the embryonic development of the heart of a mammal show a series of stages which succeed each other in the same general way from the 2-chambered to the 4-chambered condition, as is shown when we pass from the lower vertebrates, such as fishes, up through amphibia, reptiles, and birds, to mammals? Do comparative studies of brains, skeletal systems, etc. from fishes to mammals reveal a condition similar to that described in the previous problem? From what general sources have evidences for evolution been secured? Have numerous theories of evolution been proposed and what is the present-day status of each?

Read references in the text and other places to secure information concerning the problems and questions. Secure first-hand information in Nature regarding as many of them as possible. Write a REPORT on the topic **Living Organisms—Their Origins, Continuity, and Evolution**, including an accurate consideration of the following: (1) origin of life, including abiogenesis and biogenesis; (2) origin of life on the earth, including some of the theories which have been proposed; (3) continuity of life; (4) evolution, including the major sources of evidence and some of the major theories which have been proposed; (5) specific examples of evolution such as shown by birds, horses, etc.; (6) the use of vestigial structures as evidence in evolution.

Include EXAMPLES which illustrate each of the above phenomena and attempt to secure first-hand information in Nature about each one. Also include any DRAWINGS and DIAGRAMS which may illustrate certain points.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in preparing this report.

Animals and plants of the past and their records—paleontology

1. Problems

Have animals and plants of the past left records which can be interpreted scientifically for a variety of purposes? In what specific ways have plants and animals left their records? What conditions are necessary in order for "fossils" to form and for them to remain over long periods of time? Are fossils to be found in all types of rocks? How can the age of a fossil record be approximated? Are records being left by present-day organisms, and under what conditions? In what ways may studies of fossil records be significant? What are some of the general factors that may have led to the extinction of certain animals and plants in the past? Can much be learned from fossil records in the field and from scientific collections in museums? Can studies of fossil records be of value in explaining evolution and the probable ancestry of present-day forms? How are so-called geologic time charts determined and what are their values? Can studies of paleontology be of value in determining general climatic conditions at certain times in the past? Can such studies assist in determining what was sea and land in past times? Of what other practical value is a study of paleontology?

2. Preliminary observations and pertinent data and information

RECORD all of the accurate information that you may have concerning fossil records and their formation which pertains to the problems, including only that which is true.

3. Formulation of hypotheses and determination of methods of investigation

From the accurate information which pertains to the problems, formulate hypotheses from which you may work toward their solution. Record specific methods of investigation that will supply additional pertinent information.

4. Testing correctness (verification) of hypotheses by collecting additional pertinent data

The various ways in which plants and animals of the past may have left records include (1) by actual preservation of the original materials of the organism intact; (2) by preservation of skeletal structures practically unchanged; (3) by natural molds or incrustations; (4) by petrifaction; (5) by leaving trails (by animals) and imprints (impressions).

Study these methods of forming records in your text and other references. Be sure that you are familiar with each so that you may be able to recognize examples of each in your laboratory, museum, and field studies.

RECORD IN A TABLE the characteristics of each method of fossil formation. Study such representative examples of each method as may be available. Ascertain the method of forming each, its approximate age, and other pertinent information concerning it. Study a geologic time chart and attempt to place each specimen studied in its proper place in it. Make labeled DRAWINGS of such representative types as may illustrate each method.

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Were your studies sufficiently extensive and detailed so as to supply accurate, pertinent information? What additional studies might be made to supply additional data? If errors may have been made, give reasons why they were made.

6. Drawing logical conclusions based on data and facts obtained

What conclusions can you draw from the logical interpretation of the collected information? Are they valid and justified as based on the evidence? Record additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient, accurate information.

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable and pertinent information. Repeat all observations and interpretations which may have been erroneous, thereby giving inaccurate conclusions.

Early man and his records

DID EARLY MAN leave records which reveal some of his physical and mental traits, as well as some of his activities and achievements? Do some of the records include skeletal remains, ornaments, tools, and implements in various degrees of preservation and completeness? Do records suggest how early man may have used certain types of habitations, foods, as well as primitive arts and industries? In general do the remains of anthropoid ancestors suggest a descent with change as we observe them from the oldest ones found in the lower strata of the earth upward through successive strata to the most recent? In instances where no records were left might this be due, in part at least, to the fact that man was not buried sufficiently, or, if so, may his remains have been destroyed by fire or natural causes before a record could be formed? Are valuable records of early man and his ancestors being discovered today, and may these help to substantiate earlier theories which were proposed concerning his history and culture?

Study references in your text and other places which give information pertaining to the problems and questions. Study museum specimens, charts, models, lantern slides, film strips, movies, etc., which may supply pertinent information.

Write a REPORT on the topic **Early Man and His Records,** including the information suggested on accompanying pages. Fill in the spaces with accurate information for each representative selected.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in writing the report.

Name ____________________

Section ____________________

Date ____________________

EARLY MAN AND HIS RECORDS

	Cro-Magnon or modern man *(Homo sapiens)*
Where records were found	
Age (epoch, period, and era)	
Approximate date (B.C.)	
Cranial capacity and brain development	
Development of chin	
Characteristics of skull and skeleton	
Activities and achievements ("culture")	

Name ______________________

Section ______________________

Date ______________________

EARLY MAN AND HIS RECORDS (cont'd)

	Neanderthal man *(Homo neanderthalensis)*	**Heidelberg man** *(Palaeanthropus [Homo] Heidelbergensis)*
Where records were found		
Age (epoch, period, and era)		
Approximate date (B.C.)		
Cranial capacity and brain development		
Development of chin		
Characteristics of skull and skeleton		
Activities and achievements ("culture")		

Name ______________________

Section ______________________

Date ______________________

EARLY MAN AND HIS RECORDS (concluded)

	Peking man (*Sinanthropus pekingensis*)	**Java ape-man; erect ape-man; Trinil man** (*Pithecanthropus erectus*)
Where records were found		
Age (epoch, period, and era)		
Approximate date (B.C.)		
Cranial capacity and brain development		
Development of chin		
Characteristics of skull and skeleton		
Activities and achievements ("culture")		

Part Six

THE INTERRELATIONSHIPS OF LIVING ORGANISMS AND THEIR ENVIRONMENTS

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Living organisms and their environments—ecology

1. Problems

Are living organisms affected by their environments and, at times, are the latter changed or affected by the organisms living in them? Might environmental influences include inanimate, chemical, and physical factors, as well as other living organisms? Is all life interdependent—one living organism possibly affecting others and in turn being affected by them? Regardless of antagonisms, animosities, and struggles between living organisms, is there also a certain unity and cooperation among some organisms living in a community? Even though this unity or "web of life" may change from time to time so far as individuals are concerned, is there more or less constancy in a given region, which results in a so-called "balance in nature"? Are communities or associations of living plants and animals fixed, or do they change from time to time? Are these changes in living organisms, either on the part of individuals or by an entire community, an attempt to adjust more or less successfully to changing, nonliving and living environments?

2. Preliminary observations and pertinent data and information

RECORD accurately all information which is true and which pertains specifically to the problems. The reading of references in this connection may be helpful.

3. Formulation of hypotheses and determination of methods of investigation

From the reliable information that pertains to the problems, formulate hypotheses from which you may work toward their solution. RECORD specific methods and procedures whereby additional reliable information and data may be secured.

4. Testing correctness (verification) of hypotheses by collection of additional pertinent data

Ecology is the scientific study of the interrelationships between living organisms and their environments. An ecologic study of only one animal (or plant) may be made, or a total ecologic study (all types of animals and plants) may be made. In the latter study the problems may be more complex, yet the total results may possibly be more complete and comprehensive. In order to understand and appreciate the complex interrelationships encountered, a scientific ecologic study might be made of a pond or similar unit.

ECOLOGIC STUDY OF POND

General

1. Make a general survey of the entire pond, observing carefully its general characteristics. Divide the pond into as many different areas (divisions) as seem to make up the pond.

2. DRAW an outline MAP of the pond, properly proportioned and drawn to scale.

3. Select logical testing sites (stations) in each of the representative areas into which you have divided the pond. Each station site should be typical and representative for the area that it represents. LOCATE EACH STATION DEFINITELY on the map so that you may return to it for future samples and rechecking. Give each station a number for identification.

4. Take as many samples at each station as seem necessary to secure representative information regarding that station and, hence, for the entire area which that station represents. Place each sample from each station in a separate, clean bottle, properly labeled.

5. Collect the samples with the proper nets and other equipment supplied by the instructor. KEEP COMPLETE AND ACCURATE NOTES regarding each sample, station, etc.

6. Identify all the living organisms in each sample, RECORDING the total number of each species of plant and animal (using references supplied by the instructor).

Procedure for each station

1. RECORD the exact location of the station on the map.

2. In your NOTES describe the general conditions which you observe at that station.

3. Collect data concerning each of the environmental factors which might influence the living organisms at that station. The following outline is by no means complete but serves as a basis for the collection of pertinent data (add additional items if you find them pertinent to your investigation).

Physical factors. (1) Temperature of the water; (2) turbidity of the water (and any particular color present); (3) depth of water; (4) available amount of light at various depths (time of day, cloudiness, etc.); (5) type of bottom (solid rock, gravel, sand, mud, etc.) (smooth, creviced, etc.); (6) protection (afforded by rocks, vegetation, etc.); (7) entrance or exit of a stream (if near a station); (8) currents of water (if present); (9) presence or absence of natural "barriers," or "highways," which might affect distribution; and (10) additional physical factors.

Chemical factors. (1) The acid or base content of the water (known as the hydrogen-ion concentration, or pH); (2) the amounts of available oxygen and carbon dioxide, etc.; (3) the presence of special chemicals which might affect the distribution of living organisms; (4) the quantity and quality of available foods; (5) the quantity and quality of the subaquatic soil, and (6) additional chemical factors.

Biologic factors. (1) Observable competition between animals and plants which might influence the distribution of either, or both, in that station under its particular conditions; (2) observable cooperation between animals and plants which influences the distribution of either or both; (3) total numbers of each of the various species of living animals located in that area (as revealed in part by your sample analyses); (4) total numbers of each species of living plants; (5) influences brought about by man which might affect plant and animal life; (6) additional biologic factors.

Genetic factors (inherited structures and functions). (1) Observation of any inherited structure, function, or ability possessed by certain plants or animals which might specifically influence the distribution of that organism at that particular station.

RECORD accurately each of the above factors which may be used in the scientific explanation of the ecology of the pond.

ECOLOGIC STUDY OF PORTION OF CAMPUS

Using the same procedures as described above, make an ecologic study of a terrestrial area, such as a specific portion of the campus or similar unit. Follow the steps and procedures outlined above as carefully as possible so that accurate data may be secured. What similarities and differences do you find in the two types of ecologic investigation?

5. Evaluation of collected data and information

Do the collected data and information prove or disprove the hypotheses and problems? Did you make all observations carefully and all interpretations accurately? List any instances where errors may have been made and reasons why they were made.

6. Drawing logical conclusions based on data and facts obtained

RECORD the conclusions which you can draw from the logical interpretation of the data and information. List additional conclusions which may not be associated directly with the problems. Be sure that all conclusions are based on sufficient evidence and are valid. What practical applications can you make from your ecologic studies?

7. Rechecking all steps

Recheck all steps in the procedures which you followed in attempting to secure reliable, pertinent information. Repeat all observations and interpretations so that the information and data are as reliable as possible and the conclusions are accurate in the light of the information secured. Would an investigation of each station reveal the same results if repeated several times? Why?

Geographic distribution of plants and animals—biogeography

MAY THE WORLD be divided into natural biologic regions in each of which certain animals (and plants) are distributed in Nature? Does each geographic region have its environmental characteristics which help to influence the distribution of animals (or plants) common to that region? May a certain environmental factor (such as a body of water) serve as a "barrier" to the distribution of certain species, whereas that same factor may serve as a "highway" for the distribution of other species? May a study of the geographic distribution of animals (and plants) give us valuable information about present-day distributions but also reveal the ancestry of certain forms and the ways they have dispersed (migrated) from their original points of ancestry? May animals be assisted in their geographic distribution by such factors as (1) production of large numbers of offspring, (2) well-developed methods of locomotion, (3) no highly specialized requirements for foods, shelters, etc., (4) protective properties such as colorations, specialized structures, or other inherited abilities, (5) inherent abilities to cooperate with other living organisms? May a large country such as ours be divided into regions in each of which certain plants (and animals) are distributed naturally? Does each of such regions in our country have certain environmental characteristics which influence plant (or animal) distribution in it? May plants be assisted in their distribution by such factors as (1) production of large numbers of offspring, (2) well-developed methods of dispersal, (3) no highly specialized requirements as to soils, moisture, etc., (4) not affected too adversely by various climatic conditions, (5) inherent abilities to adjust successfully to environmental conditions? May the factors which influence the distribution of plants and animals be classed as (1) physical, (2) chemical, (3) biologic, including human, and (4) hereditary or genetic?

GEOGRAPHIC DISTRIBUTION OF ANIMALS

The scientific study of the distribution of living organisms in space is known as **biogeography.** If the study deals with animals it is called **zoogeography,** and if it deals with plants it is called **plant geography (phytogeography).**

For a study of animal distribution the world may be divided into **natural biologic regions** as follows.

1. The **Nearctic region** comprises all of North America except the tropical region. Study 5 animals inhabiting this region, including their characteristics and SPECIFIC REASONS why each is present in this region and not in other regions. Study pertinent references to make these answers worth while and accurate.

2. The **Palaearctic region** is comprised of the northern part of Asia and Europe and that part of Africa north of the Sahara Desert. Study 5 animals of this region, including their characteristics and SPECIFIC REASONS why each is present in this region.

3. The **Neotropical region** comprises the tropical part of North America, South America, Central America, and the West Indies. Study 5 animals of this region, in-

Text continued on p. 261.

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Name ____________________

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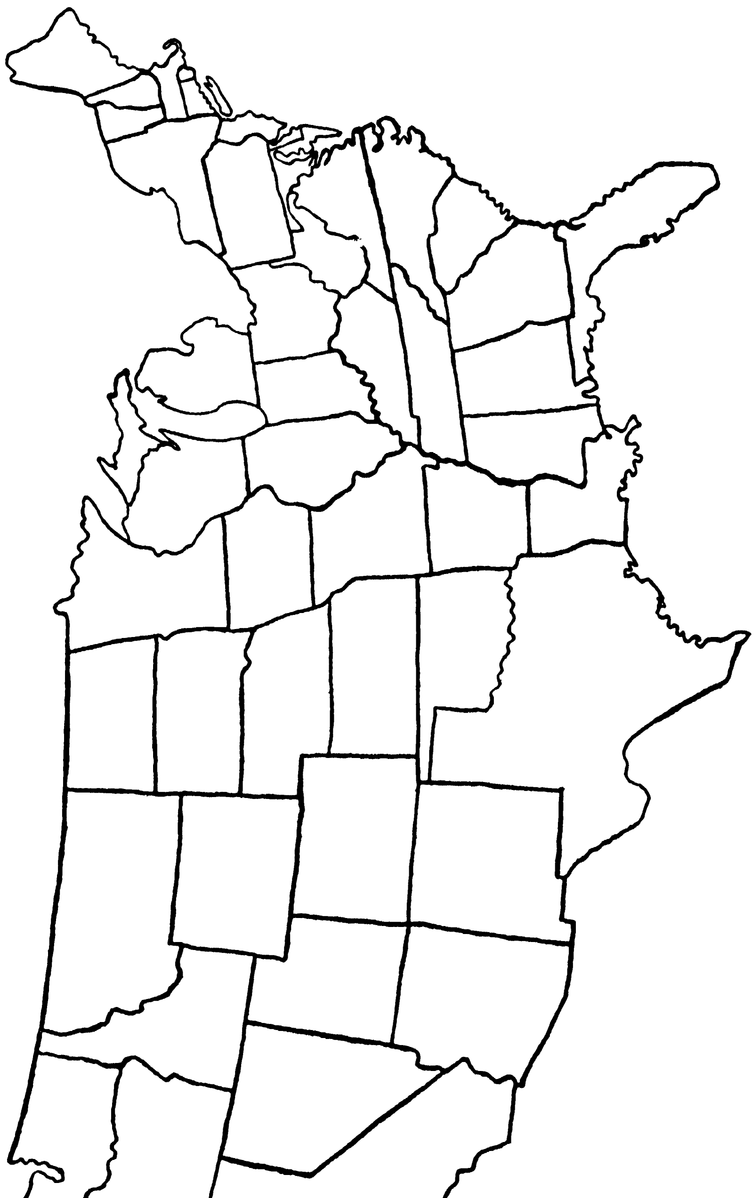
Date ____________________



cluding their characteristics and SPECIFIC REASONS why each is present in this region.

4. The **Ethiopian region** is comprised of all of Africa south of the Sahara Desert. Study 5 animals of this region, as you have for the previous regions.

5. The **Oriental region** comprises India, southern China, Philippines, Indonesia, Burma, Thailand, etc. Study 5 animals of this region as you have for previous regions.

6. The **Australian region** is comprised of Australia, New Guinea, and adjacent islands. Study 5 animals of this region as you have for previous regions.

DRAW the boundaries of the 6 regions on the world maps (on accompanying pages), placing the name of each region correctly. Hand in these maps with your studies of the 30 animals. If possible, study museum specimens or pictures of each animal discussed. Study charts and references in the text, in natural histories, atlases, encyclopedias, etc.

WRITE A REPORT, using the following outline: (1) name of the geographic region, (2) general boundaries of the region, (3) environmental characteristics of the region, and (4) 5 animals which inhabit the region naturally, including SPECIFIC REASONS why you think each animal is distributed as it is. Do not include domesticated animals or those held in captivity. Why? The selection of animals may include various types or only one type (that is, birds) if you happen to be interested particularly in one type.

Repeat the 4 points mentioned above for each of the regions, including 5 animals for each region.

What CONCLUSIONS can you draw from the logical interpretation of the information collected in your studies? List as many of them as possible at the end of your report, being sure that all of them are valid and justified as based on reliable, pertinent evidence.

GEOGRAPHIC DISTRIBUTION OF PLANTS

Just as the world may be divided into natural biologic regions for animal distribution, so it might be divided into areas for plant distribution. Distribution studies may include useful, cultivated plants, or so-called "wild" types. In this study we shall limit ourselves to a few cultivated, or economically important, plants in the United States. Many of the factors which are influential in the distribution of plants in a study of plant ecology are likewise of importance in the study of plant geography.

Study the distribution in the United States of the following (or as many as suggested by the instructor): (1) wheat, (2) corn, (3) cotton, (4) deciduous trees, (5) northern evergreens, (6) southern evergreens, (7) citrus fruits, and (8) additional plants. Study each of the plants from such references as the text, atlases, economic geographies, encyclopedias, etc.

WRITE A REPORT, using the following outline: (1) name of the geographic area, (2) general boundaries of the area (also DRAWN on the map on an accompanying page), (3) environmental characteristics of the region, and (4) SPECIFIC REASONS why you think the plant is distributed as it is.

Repeat the 4 points just mentioned for each plant studied.

What CONCLUSIONS can you draw from the logical interpretation of the information collected in your studies? List as many as possible at the end of your report, being sure that all of them are valid and based on sufficient reliable, pertinent evidence.

Unity, interrelationships, and similarities in the living world

IN GENERAL is there relatively more unity and cooperation than antagonisms among the various living organisms? In general, in a normal organism must there be unity within the cell, unity and cooperation between the various cells of tissues, cooperation between the various tissues of the organs, cooperation between the various organs of the systems, and cooperation between the various systems if that organism is to live successfully? In closely related species of organisms are there some similarities of structures and functions? In some instances is there unity and cooperation between different types of organisms, as illustrated by the nitrogen cycle, the carbon cycle, the oxygen cycle, and the sulfur cycle? Are there so-called successions in biologic communities (associations) of plants and animals? Do most living organisms depend, either directly or indirectly, upon the process of photosynthesis in chlorophyll-bearing plants? Are living organisms associated in what might be called a "web of life"? When all of the cooperations and antagonisms of living organisms in a community are considered as a whole, is there really what is known as a "balance in nature"? When the balance in a community is upset temporarily by the elimination of individuals or groups or by the additions of individuals or groups, is there a natural tendency to reach a new balance? Do many animals have a tendency to disperse or migrate from their points of birth? What effects might such a procedure have? Do many plants have abilities to be dispersed (through methods of reproduction) from their points of origin? What effects might such a procedure have on them as well as the area into which they have moved?

Read references in the text and other places in order to secure information concerning the questions and problems. WRITE A REPORT on the topic **Unity, Interrelationships, and Similarities in the Living World**, including an accurate consideration of each of the following (1) unity within each living organism, (2) similarities of structures and functions between closely related species of organisms, (3) unity and cooperation between various types of organisms, as illustrated by the nitrogen cycle, carbon cycle, oxygen cycle, and sulfur cycle, (4) biologic communities (associations) and successions of plants and animals, (5) the dependence of most living organisms, directly or indirectly, on the process of photosynthesis, (6) the "web of life" and "balance in nature," (7) migrations and dispersals of animals and plants.

Include EXAMPLES that illustrate each of the above phenomena and attempt to secure first-hand information in Nature about each one. Also include any DRAWINGS and DIAGRAMS that may illustrate certain points.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in preparing this report.

Special kinds of interrelationships among organisms

MAY LIVING ORGANISMS live together in a great variety of biotic relationships, extending from more or less complete dependence on the one hand to more or less complete independence on the other? May biotic relationships exist between different species of plants, different species of animals, and between plants and animals? May plants or animals be parasitic on certain other living plants and animals? May certain pathogenic (disease-producing) plants cause diseases in other plants, in animals, and in human beings? May certain pathogenic animals cause diseases in plants, in other animals, and in man? Are a majority of the plants that are pathogenic for plants and animals found principally in the lower types such as bacteria, molds, and yeasts? Are animals that are pathogenic for other animals found principally among the protozoans, flatworms, roundworms, and arthropods? Are animals that cause damage to plants found principally among the flatworms, roundworms, and arthropods? Are symbiosis, mutualism, and commensalism of rather frequent occurrence in the living world, and what is the significance of each? Is gregariousness rather common among living organisms and what benefits or harmful effects might the participants derive from such a method of living? May biotic communities (associations) of plants and animals undergo what is commonly called successions? Do all of the species of organisms living in a given area or habitat constitute a biotic community which is composed of intimately associated smaller groups called populations? Might a population be defined as a group of plants or animals of the same species which live in a given area? Is one of the most important interrelationships of organisms known as a food chain (food pyramid), and what is the significance of this phenomenon? How common is predatism among animals, and is it beneficial or detrimental? Are insectivorous plants (carnivorous plants) so constructed as to secure nourishment by the enzymatic digestion of animal materials? Do certain plants known as epiphytes use other plants, poles, trees, and wires for support but do not derive nourishment from the other plant to which they may be attached? Are there numerous organisms that are saprophytes, therefore living on such dead, organic materials as carbohydrates, proteins, etc., and securing their nourishment through the actions of enzymes which they secrete? Are viruses considered to be living or nonliving? Can viruses be cultivated only in the presence of living protoplasm? Are most viruses filtrable and extremely small? Can viruses be demonstrated by the electron microscope? Are certain bacteria attacked by viruses known specifically as bacteriophages? Do viruses cause many diseases in plants, animals, and human beings? Do such pathogenic plants as *Puccinia graminis* (black stem rust of wheat) and such pathogenic animals as liver flukes undergo complex life cycles in two or more living hosts?

Read references in the text and other places to secure information concerning the questions and problems. Write a REPORT on the topic **Special Kinds of Interrelationships Among Organisms,** including an accurate consideration of each of the following: (1) parasitism, (2) symbiosis and mutualism, (3) commensalism, (4) gregariousness, (5) biotic communities (associations) and populations, (6) predatism, (7) insectivorous (carnivorous) plants, (8) epiphytism, (9) saprophytism, (10) viruses, including bacteriophages.

Include EXAMPLES which illustrate each of the above phenomena and attempt to secure first-hand information in Nature about each one. Also include any DRAWINGS and DIAGRAMS that may illustrate certain points.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in preparing this report.

Part Seven

MAN'S USE OF BIOLOGY—PAST, PRESENT, AND FUTURE

55

Applied biology

DO PLANTS AND ANIMALS play important roles as the sources of many of our foods and in the preparation of some of them? Do many of the materials used in the making of our clothing and furniture have their origins in plant and animal products? Do many of our common fuels originate from plant and animal materials, either of the present or of the past? Does much of the equipment used for recreational purposes have source materials that originate from animal and plant products? Do some of our medicines have plant or animal origins? Do animals serve as testing subjects before certain medicines and drugs are generally used by man? Does much of our annual wealth depend upon plant and animal products? Are plants and animals associated with the causes, transmission, prevention, and treatment of many diseases of man and animals? What part does biology play in such important health-related programs as water supplies, sewage disposal, garbage disposal, and sanitation? What role does biology play in the training of the personnel of a city (county, state, or national) health department? Are some of the laboratory technics employed by health departments associated with biology?

Thousands of plants and animals play important roles in the economy of Nature and they are of great economic value to man, as the following will illustrate.

Biology in its relation to foods, clothing, furniture, fuels, recreation, medicines, and wealth

Write a REPORT on this topic, including the following items.

1. List 20 common **foods** and tell how each is related to plants and animals as to source and method of preparation.
2. List 10 common types of **clothing** and tell how each is related to plants and animals as to source and method of preparation.
3. List 10 articles of **furniture** and tell how each is related to plants and animals as to sources of materials from which each is constructed.
4. List all of the common types of **fuels** and tell how each is related to plants and animals, either past or present, as to the source and method of production.
5. List several **types of recreation,** showing in each case how the actual construction of the necessary recreational equipment is directly or indirectly dependent upon plant or animal products.
6. List several **medicines** which have plant or animal origins either directly or indirectly. Do animals serve as experimental subjects in testing various medicinal products before they are generally used by human beings? List several specific examples to prove your point.
7. Plants and animals, either directly or indirectly, are the source of much of our **wealth.** By using the proper references, ascertain and record the total annual value of each of the following, including the year when each was evaluated and the specific source of the data: (a) corn, (b) wheat, (c) lumber, (d) coal, (e) petroleum and gasoline, (f) leather, (g) furs, (h) hay, (i) fishes, (j) beef, (k) milk and dairy products, (l) pork, (m) poultry and poultry products, (n) textiles and clothing, (o) paper and paper products, (p) medicinal plants and animals, (q) other

miscellaneous products either directly or indirectly dependent on plants or animals.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in writing this report.

Biology in its relation to diseases, their causes, transmission, prevention, and treatment

Write a REPORT on this topic, including the following items.

1. List 20 **human diseases which are caused by plants** (such as bacteria, molds, and yeasts), giving the name of the disease, the specific causal agent, and the general characteristics of each disease.
2. List 10 **human diseases which are caused by animals** (such as protozoans, flatworms, roundworms, and arthropods), giving the name of the disease, the specific causal agent, and the general characteristics of each disease.
3. List several **human diseases which are transmitted by animals,** giving the name of the disease and the name of the animal transmitting the specific causal agent.
4. List 10 **human diseases which are caused by viruses,** giving the name of the disease and the general characteristics of each disease.
5. List several common **antibiotics** (such as penicillin, streptomycin, etc.), giving the source (plant?) of each, a short discussion of the method of preparation, and the diseases in which each has been used successfully.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in writing this report.

Biology in its relation to water supplies, sewage disposal, garbage disposal, sanitation, and health departments

Write a REPORT on this topic, including the following items.

1. Make a study of the **water supply** of a city with which you are familiar, including such points as (a) the source of the water supply; (b) the nature of and specific sources of the pollution and contamination; (c) specific methods employed to eliminate or at least diminish the pollutions and contaminations in order to make the water usable.
2. Make a study of the method of **sewage disposal** employed by a city, including such points as (a) the specific method used by the sewage disposal plant in the treatment of the sewage; (b) the method of disposal of the sewage after it has been treated at the plant.
3. Make a study of the method of **garbage disposal** of a city, including (a) the method of collecting the garbage; (b) the method of transporting it; (c) the specific method of disposal; (d) the ill-effects to a community if the garbage is not disposed of properly.
4. Make a study of the **sanitation and health departments** of a city, including (a) the personnel (doctors, nurses, inspectors, laboratory technicians, bacteriologists, etc.), giving the duties of each; (b) the role of the department in ensuring a good quality of milk and dairy products; (c) the role of the department in the inspection of meats and other foods; (d) the role of the department in the supervision of the preparation and serving of foods in public eating places; (e) the role of the department in the diagnosis, quarantine, and treatment of various diseases; (f) the role of the department in connection with the health of students; (g) the way in which the department is supported financially.

At the end of the report state as many CONCLUSIONS as you can draw from these studies. Also include a list of bibliographic references which you used in writing this report.

Genetic improvements of living organisms—plants, animals, and human beings

How many types of plants and animals have been improved by the scientific application of certain genetic procedures? Is it possible for man to improve living organisms because of an inherent variability which they possess? Why are a majority of the variations caused by the direct action of environmental influences not heritable, whereas those variations which are determined by the genic constitution of the organism may be transmissible? Have many of the types of cultivated plants that serve human needs been developed by selection, or hybridization, or a combination of the two? Are mass culture and pedigree culture two of the important methods of selection in plant breeding? Does the mass culture method of plant breeding involve breeding from a selected group (mass) of individuals which vary in some desirable direction? If seeds collected from superior plants which possess the desired trait are sowed en masse and the selective process is continued in successive generations, may an improved race be obtained eventually?

In the pedigree culture method are single plants with desirable traits selected to form the basis of the improved race? In the pedigree culture method is an accurate record (pedigree) kept of the offspring of each selected individual, and after several generations is the best strain then retained? In many instances must improved plants be prevented from crossing with plants with inferior, undesirable traits? Is the genetic method of hybridization used extensively so that traits of two different parents are combined in the offspring? Is the recent improvement of corn the result of the hybridization process?

Are most of the problems of the animal breeder rather complex because many of the traits with commercial value are dependent upon the interaction of multiple genes? Hence, must most technics for the improvements of commercial types of animals involve selections based on quantitative variations? Must close inbreeding almost always accompany artificial selection for racial improvements by retaining desirable genetic traits in animals that possess them? Is outbreeding a desirable method of introducing new genes into a population of animals in order to increase the possibilities of selection for certain traits? Is the production of mutations which have been induced by artificial means a desirable method of introducing new traits? Can a race be improved by taking advantage of a mutation which occurred naturally? Are most mutations better or worse than the organism originally?

In general are improvements in human traits which are due to the direct action of environmental influences, transmissible to future generations? What are some of the difficulties in attempting to improve human beings by genetic methods? What eugenic methods might be applied profitably in human racial improvement? What genetic effects might modern warfare have on the human race? What effects might migrations have on the population of the new country, as well as on the population of the country from which they migrated?

Practically all domesticated animals and cultivated plants have been improved genetically to a greater or lesser extent. Many of the plants and animals which we use were originated from so-called "wild" types and certain traits have been improved by genetic and environmental methods. In order to get an idea of this marvelous, scientific progress the following studies are suggested. Read in your text and other selected references how plants and animals have been improved.

In your collection of information, if possible, ascertain the so-called "wild" ancestor, the method of improvement employed, and the name of the organism with its desirable traits listed briefly. Following this suggestion, secure this information concerning 15 **domesticated animals** and 15 **cultivated plants.**

Write a REPORT on **The Genetic Improvements of Plants and Animals,** using the above suggestions and any other pertinent information which may be available for the specific animals and plants being studied. At the end of the report add all CONCLUSIONS you can logically draw from your studies.

Study your text and other selected references regarding the eugenic improvements of human beings, and hence the human race. Write a REPORT on the topic **Improvement of the Human Race—Eugenics,** including the problems involved, the difficulties which are to be encountered, the methods that might be employed profitably, and the possible results that might be expected. Also include probable reasons why man has not made too serious an attempt to improve the race, in spite of the fact that he has sufficient knowledge of the necessary procedures to be followed. Include also the role of education in presenting the scientific facts of eugenics to the general public. Add brief accounts of eugenic programs in certain states and countries where they seem to be functioning rather profitably.

At the end of the report add all CONCLUSIONS which you might logically draw from your studies of human eugenics. Also include a list of bibliographic references which you used in writing this report.

Diseases—immunity and defenses

MIGHT DISEASES be classified into two categories, infectious and noninfectious? Might we classify infectious diseases into two categories, communicable and noncommunicable? What conditions must be fulfilled before an infection can take place? What were some of the early theories of diseases and how were they scientifically disproved or proved? Are the so-called three lines of defenses among the most important deterrents to the production of diseases in man? Do the productions of such antibodies as antitoxins, agglutinins, bacteriolysis, opsonins, etc., play important roles in defense? Can immunity to certain diseases be secured through actively acquired immunity, through passively acquired immunity, or both? What roles do sulfonamide ("sulfa") drugs play in connection with certain diseases? What are some of the useful antibiotics and for what purpose is each used? When were antibiotics first discovered and how did the modern production and application of them originate? Are certain diseases of plants, animals, and human beings produced by various types of plants? Are certain diseases of plants, animals, and human beings produced by various types of animals? What are the causes and effects of so-called food poisonings? Do so-called allergies result from the stimulation of tissue cells by substances called allergens, with the production of an allergic reaction?

Read references in your text and other places on the topic **Diseases—Immunity and Defenses** and write a REPORT, including suggestions given above and any other pertinent information that may make the report as complete and meaningful as possible. Include several specific examples of diseases of both plants and animals (including man) which are caused by various types of (1) plants and (2) animals.

At the end of the report add all of the CONCLUSIONS which you can logically draw from your studies. Also include a list of bibliographic references which you used in writing the report.

Conservation of resources—saving for ourselves and the future

WHAT CONSTITUTE the resources of a country? Do our forests constitute major resources and may our continued exploitation still reduce them greatly? Can soil fertility be improved by certain remedial measures, including the proper uses of plants and animals, in some instances by using plants in ways which are not being utilized, and in other instances by not using plants in ways in which they are being used incorrectly at present? Can soil erosions by water, winds, etc., be alleviated by the correct employment of proper methods of plowing, planting, etc.? Can water resources be improved and maintained where they are needed most if man will utilize plants on watersheds more wisely, eliminate undesirable plants and animals from sources of water supplies, prevent unnecessary contamination and pollution of existing water supplies, etc.? Can some of our diminishing resources be replaced if man follows a natural, scientific program for their propagation and maintenance particularly in such areas as wild life (plant and animal), fishes, grasslands, forests, etc.? Do human beings constitute important resources in a country? Can human resources be improved and maintained by scientific applications of biologic knowledge in such areas as health, disease prevention and cure, scientific experiments with animals and plants, improving the quality of foods, improving human beings by the scientific application of our knowledge of heredity, etc.? Can the total program of the conservation of resources be inaugurated and put into practice through the proper education of man concerning the problems involved, the causes for the losses, the consequences if these losses are continued, and specific scientific programs whereby these highly essential resources may be replenished?

Read references in your text and other places which pertain to the problems of conservation. Write a REPORT, including the items listed below and answering the questions and problems involved in each instance. For convenience the report may be divided into several smaller sections as suggested below.

In collecting facts and data make as many observations from actual cases in the field as possible. If you are not too familiar with the actual conditions, make additional observations and read additional references in order to secure the most reliable information possible. For example, if you are interested in wild life, make actual, out-of-door studies of the causes for the loss of wild life and the actual consequences which may result from such losses. Also formulate scientific methods which might result in the reduction of these losses.

In order to make your studies somewhat extensive and comprehensive, each resource might be considered along the following lines, (1) causes for the loss or diminution of the resource, (2) effects which may result if we continue our present methods of destruction and improper use, and (3) specific scientific programs which might assist in regaining and maintaining each resource.

Conservation of forests. Study and write a REPORT on a certain **forest** which has been destroyed. Include (1) the specific causes of the destruction, (2) detrimental effects of the destruction, (3) specific methods that might have prevented the destruction, (4) benefits when the results of the destruction are corrected, and (5) specific conservation measures which are (or should be) employed to correct the conditions.

Conservation of soils. Study and write a REPORT on a certain area of **soil** which has been eroded by water or wind, or both. Include in this study (1) causes of this erosion, (2) detrimental effects of the erosion, (3) specifically how the erosion might have been prevented, (4) benefits when the results of the erosion are corrected, and (5) specific conservation measures which should be employed to correct the conditions.

Conservation of water. Much of our diminishing water supply is being polluted and contaminated so that the available supply is decreased still further. Study and write a REPORT on a **stream of water** which is contaminated or polluted. Include in the report (1) the specific causes of the pollution or contamination, (2) the harmful results of such pollution or contamination, (3) specific ways how the pollution or contamination might have been prevented, (4) benefits when the results of the contamination or pollution are corrected, and (5) specific conservation measures which should be employed to correct the conditions.

Conservation of wild life. Select a certain type of **wild life**, the supply of which is being depleted. Write a REPORT, including (1) specific causes for the loss or depletion of this particular type of wild life, (2) harmful results of such a loss, (3) specific methods that might have prevented the loss, (4) benefits when the proper remedial measures are taken, and (5) specific conservation measures which should be taken to correct the conditions.

Conservation of fishes. Select a stream or other body of water in which the supply of **fishes** is decreasing or has ceased to exist. Write a REPORT, including (1) specific causes for this loss, (2) harmful results of such a loss, (3) specifically how the loss might have been prevented, (4) benefits when the proper remedial measures are taken, and (5) specific conservation measures which should be taken to correct the conditions.

Conservation of human resources. Write a REPORT on **human resources**, including (1) those items which we might classify as human resources, (2) specific ways in which these resources are being dissipated, (3) harmful consequences when these important resources are lost or dissipated, (4) beneficial results when these losses are prevented, and (5) specific remedial measures which should be taken to prevent these unnecessary losses.

At the end of the report add all of the CONCLUSIONS which you can logically draw from your studies. Also include a list of bibliographic references which you used in writing this report.

National Parks

CAN NATIONAL PARKS (or other Federal, State, or similar recreational facilities) be considered as resources? In what ways can such facilities serve valuable purposes? When and where was the first National Park established? When and where was the most recent National Park established? What is the total number of National Parks and in which state is each located? How are the funds for their operation supplied? How many National Parks have you visited and what information did you derive from each? Which National Park do you consider to be the most interesting, giving specific reasons why you say so?

Read references in your text and other places which provide accurate, pertinent information on National Parks. Numerous publications published by the National Park Service of the Department of Interior will be very helpful and educational.

Write a REPORT on **National Parks,** including (1) the name, location, and date of establishment of each, and (2) special attractions and characteristics of each National Park.

At the end of the report add all the CONCLUSIONS which you can draw logically from your studies. Include the great benefits derived from our parks by the large numbers of our citizens. What are some of the factors responsible for the great attendance at such areas as National Parks, National Monuments, National Memorials, State parks, etc. in recent years?

Also include a list of bibliographic references which you used in writing this report.

Part Eight

APPENDIX

Appendix I

Classification and identification of plants (a key)

OBSERVE CAREFULLY the characteristics of the specimens supplied by the instructor. Compare these characteristics with the descriptions in the key, starting with **I.** In case this description does not apply, pass to II, reading descriptions under **A** and **AA.** Then compare your specimen with descriptions under succeeding subdivisions until a correct identification is reached. Because of limited space certain details are not given so that certain plants may not be identified too easily. For more detailed keys the instructor may supply additional references.

I. Plant body simple and undifferentiated; no true leaves, stems, or roots; no vascular tissues (no xylem and phloem tissues); gametes (sex cells) enclosed only by a cell wall; zygote does not develop into an embryo while still enclosed within female sex organ . . . . **Subkingdom Thallophyta** (thallus plants, or thallophytes)

A. Thallophyte plants with chlorophyll (some have additional pigments which mask chlorophyll); commonly called "algae"

(1) Plants without organized plastids; without organized nucleus; plant body unicellular or colonial; no motile stages known; color due to bluish pigment (phycocyanin) primarily, but few species also possess red pigment (phycoerythrin); no sexual reproduction; food stored as starchlike carbohydrate; common in damp places and in marine and fresh water . . . . **Phylum Cyanophyta** (blue-green algae)

(2) Plants with organized plastids; organized nucleus; plant body usually unicellular and naked; motile cells have 1 to 3 anterior flagella; color due to chlorophyll and associated carotenoid pigments; reproduction by longitudinal cell division (one genus reproduces sexually); some form thick-walled resting cells, called cysts, which germinate into motile cells; foods stored as paramylum (starchlike carbohydrate), and fats; common in fresh water, especially if rich in organic materials . . . . **Phylum Euglenophyta** (euglenoids)

(3) Plants with organized plastids; organized nucleus; plant body unicellular, colonial, or multicellular, and may be motile or nonmotile; color due to chlorophyll and associ-

Continued on next page.

ated carotenoid pigments; asexual reproduction by fragmentation, motile zoospores, nonmotile spores; sexual reproduction by isogamy, heterogamy, or oogamy; food stored as starch; most are fresh-water types; some in soils and on rock; few marine types . . . . **Phylum Chlorophyta** (green algae)

(4) Plants are motile or nonmotile unicellular forms, and filamentous and nonfilamentous colonial types; color due to chlorophyll and fucoxanthin pigment; asexual reproduction by cell division (rarely by isogamy); foods stored as leucosin (insoluble carbohydrate), oils, or volutin (insoluble food in diatoms); many fresh water types, with some species in soils or damp places, and few are marine . . **Phylum Chrysophyta** (yellow-green algae, golden brown algae, and diatoms)

(5) Plant body usually large, complex, and nonmotile; organized plastids; organized nucleus; motile cells have 2 lateral, unequal flagella; color due to chlorophyll and also fucoxanthin; asexual reproduction by fragmentation, motile zoospores, nonmotile spores; sexual reproduction by isogamy, heterogamy, or oogamy; all possess alternation of generations between a sporophyte and gametophyte plant; stored foods sugars and fats; primarily marine, especially in colder waters . . . . **Phylum Phaeophyta** (brown algae)

(6) Plant body multicellular, simple or branched, and rarely more than few inches long; organized plastids; organized nucleus; no motile cells; color due to chlorophyll, phycoerythrin (red), and phycocyanin (bluish) pigments; most species reproduce sexually; many species possess alternation of generations; stored foods "floridean starch" insoluble carbohydrate between true starch and dextrose (sugar); protoplasmic strands characteristically connect adjacent cells; primarily marine; few in fresh water; usually in warmer waters . . . . **Phylum Rhodophyta** (red algae)

AA. Thallophyte plants without chlorophyll, although another nonchlorophyll, green pigment may be present in some types; these plants commonly called "fungi"

(1) Unicellular fungi reproducing asexually by fission (cell division); usually without filamentous hyphae; chromatin scattered throughout cell; nonmotile or motile with flagella (depending on species); cells may be spherical (coccus), rod-shaped, spiral, or filamentous; certain types produce single endospores . . . . **Phylum Schizomycophyta** (bacteria)

(2) Plant body a naked, slimy mass of protoplasm called plasmodium; organized nuclei; no filamentous hyphae; locomote by amoeboid pseudopodia; spores commonly produced in sporangia (spore cases); sexual reproduction by isogamy, fusion of myxamoebae; live in damp places on dead leaves, wood, etc. . . . . **Phylum Myxomycophyta** (slime fungi)

(3) Plant body usually composed of filamentous hyphae; organized nucleus . . . . **Phylum Eumycophyta** (true fungi) (See 3a, 3b, 3c)

(3a) Vegetative hyphae usually nonseptate (without cross walls); asexual reproduction by sporangiospores in spore cases (aquatic species produce motile zoospores); sexual reproduction by heterogamy or isogamy . . . . **Class Phycomycetes** (algalike [filamentous] fungi)

(3b) Hyphae septate (with cross walls), but yeasts are without hyphae; reproduce by ascospores in saclike ascus; certain types may reproduce asexually by conidiospores (*Penicillium, Aspergillus,* etc.), or by budding (yeasts) . . . . **Class Ascomycetes** (ascus [sac] fungi)

(3c) Hyphae septate; reproduce by basidiospores on paddle-shaped basidia; depending on species, other methods of reproduction include conidiospores, chlamydospores, uredospores, teliospores, aeciospores . . . . **Class Basidiomycetes** (club [basidium] fungi)

II. More complex plants with zygote developing into multicellular embryo while still enclosed within multicellular archegonium (female sex organ) or within embryo sac . . . . **Subkingdom Embryophyta** (embryophytes)

A. Multicellular plants without true leaves, stems, or roots, although certain structures may resemble them (that is, leaflike appendages, stemlike axes, rootlike rhizoids); no vascular, conducting tissues (no phloem or xylem); no stomata present; gametophyte (gamete-producing) generation conspicuous; sporophyte (spore-producing) generation unbranched and attached (parasitic) to gametophyte; multicellular antheridia (male sex organs) and archegonia (female sex organs) and with outer layer of sterile cells . . . . **Phylum Bryophyta** (liverworts and true mosses)

(1) Plant body usually prostrate, thalluslike, lobed, and flattened dorsiventrally (as in thalloid liverworts), or "leafy" (as in leafy liverworts); gametophyte conspicuous; sporophyte attached (parasitic) to female plant, disappearing after spores mature; spore capsule may open irregularly or by 2 valves . . . . **Class Hepaticae** (liverworts)

(2) Plant body rather short, "leafy," and erect or prostrate; gametophyte with leaflike appendages on stemlike axis; long-lived; sporophyte parasitic on female gametophyte, disappearing after spores mature; spore capsule opens by means of lid . . . . **Class Musci** (true mosses)

AA. Multicellular plants with true leaves, stems, and roots; vascular, conducting tissues (phloem and xylem); stomata present,

Continued on next page.

especially in leaves; sporophyte generation conspicuous and independent; gametophyte smaller and inconspicuous; female archegonia usually present (except in flowering plants, angiosperms) . . . . **Phylum Tracheophyta** (vascular plants)

B. Small, true, green leaves; true roots and stems; vascular system simple; usually perennial rhizome (underground stem) with aerial stems; sporangia borne on upper surface of sporophylls (spore-bearing leaves), and usually concentrated in club-shaped strobilus (cone) . . . . **Subphylum Lycopsida**
Class Lycopodineae
(club "mosses")

BB. Reduced leaves, often wedge-shaped or scalelike and in whorls at stem nodes; true roots, rhizomes, aerial, jointed stems and branches; simple vascular system; stems usually rough and abrasive, containing silica; usually one kind of spore formed in 5 to 10 sporangia on shield-shaped sporangiophore arranged in strobilus (cone) . . . . **Subphylum Sphenopsida; Class Equisetineae**
(horsetails)

BBB. Well-developed leaves which are often large and conspicuous; complex vascular system of diverse structures . . . . **Subphylum Pteropsida**
("higher plants")

(1) Leaves (fronds) "featherlike" or "fernlike" and bear spores on undersurface; no seeds formed; conspicuous sporophyte is perennial, whereas flat, heart-shaped gametophyte dies after new sporophyte which arises from it becomes independent; all common ferns (except "water ferns") produce one type of spore (homosporous); rhizome frequently present and bears fronds . . . . **Class Filicineae**
(ferns)

(2) Leaves often needlelike or scalelike; without true flowers; seeds borne on upper surface of open scales often concentrated in cones; hence, seeds exposed (naked) . . . . **Class Gymnospermae**
(gymnospermous plants such as the conifers and their relatives)

(3) Plants with true flowers of great diversity and with seeds enclosed in ovary; ovules (immature seeds) produced on carpels (sporophylls) which grow into closed structure; leaves usually broad and large; vascular tissues of xylem composed of long, continuous, tracheal tubes (derived by fusion of single cells) . . . . **Class Angiospermae**
(angiospermous [flowering] plants) (See 3a and 3b)

(3a) Embryonic seed leaves (cotyledons) 2 in number; leaves generally net-veined; floral organs (flower parts) mostly in 4's or 5's or multiples of them; vascular tissue of stem in shape of cylinder; cambium present; woody plants and herbs . . . . **Subclass Dicotyledoneae** (dicotyledonous plants)

(3b) Embryonic seed leaf (cotyledon) 1 in number; leaves parallel-veined; floral organs usually in 3's or multiples of 3; vascular tissues of stem usually in scattered vascular bundles; cambium usually absent; mostly herbs and few trees . . . . **Subclass Monocotyledoneae** (monocotyledonous plants)

Appendix 2

Classification and identification of animals (a key)

OBSERVE CAREFULLY the characteristics of the specimens supplied by the instructor. Compare these characteristics with the descriptions in the key, starting with **I.** In case this description does not apply, pass to **II**, reading the descriptions under **A** and **AA.** Then compare your specimen with descriptions under **B** and **BB**, continuing in this same manner until proper identification is reached. Because of limited space some details are not given so that certain animals may not be identified too easily. For more detailed keys the instructor may supply additional references.

I. Animal unicellular (acellular) or colony of similar cells; microscopic forms usually; noncellular organelles present . . . . . **Phylum Protozoa** (protozoans)

- **(1)** Locomote by means of temporary pseudopodia ("false feet") . **Class Sarcodina** (Amoeba, etc.)
- **(2)** Locomote by means of one or more whiplike flagella . . . **Class Mastigophora (Flagellata)** (Peranema, Noctiluca, Trypanosoma, etc.)
- **(3)** Locomote by means of hairlike cilia . . . . **Class Infusoria (Ciliata)** (Paramecium, etc.)
- **(4)** Nonmotile (in adult); parasitic; reproduce by spores . . . **Class Sporozoa** (Monocystis, Plasmodium, etc.)

II. Animal multicellular

- **A.** Not segmented (nonmetameric)
  - **B.** Radial symmetry or asymmetry (no symmetry)
    - **C.** Body with pores and canals . . . . **Phylum Porifera** (sponges)
      - **(1)** Skeleton of calcareous (limy) spicules . . . . **Class Calcarea** (Scypha [Grantia], Leucosolenia)
      - **(2)** Skeleton of siliceous (glasslike) spicules . . . . **Class Hexactinellida** (sand and glass sponges, as Venus's flower basket, etc.)
      - **(3)** Skeleton of spongin fibers alone, or with siliceous spicules . . . . **Class Demospongiae** (commercial sponges)
    - **CC.** Body without pores and canals; cylindrical or umbrella-shaped with a gastrovascular cavity; tentacles with nematocysts ("stinging cells") present . . . . **Phylum Coelenterata (Cnidaria)** (coelenterates)

(1) Colonial types usually; polyps (attached forms with mouth and tentacles at free end); may produce medusae (umbrella-like forms) by budding; when medusa formed it has membranous velum on underside; tentacles may be solid (as in Obelia), or hollow (as in Hydra, Gonionemus); usually an alternation of asexual hydralike generation with sexual jellyfish-like generation . . . **Class Hydrozoa** (Hydra, Obelia, Gonionemus)

(2) Solitary types; umbrella shaped; free floating usually; usually large (1 inch to 6 feet in diameter); medusa without velum; medusa differs from (1) by having 8 notches on margin of umbrella . . . **Class Scyphozoa** (true jellyfishes)

(3) Solitary or colonial types; large polyp stage but no medusa stage; gastrovascular cavity divided into chambers by radially arranged mesenteries; some types (that is, corals) have calcareous skeletons . . . **Class Anthozoa** (sea anemones, corals, etc.)

CCC. Body covered with skeleton of calcareous plates with spines; usually 5 antimeres (parts of radially symmetrical animal) or multiples of 5 (considered to have biradial symmetry by some); marine forms . **Phylum Echinodermata** (echinoderms)

(1) Typically pentamerous (5 similar parts); arms not sharply differentiated from central disk; ambulacral grooves on ventral (oral) side of arms . **Class Asteroidea** (starfishes)

(2) Typically pentamerous; slender, flexible arms sharply differentiated from central disk; no ambulacral grooves . . . **Class Ophiuroidea** (brittle stars, serpent stars)

(3) Without free arms; body disk-shaped or semiglobular; skeleton of rows of fused, calcareous plates; long calcareous spines (sea urchins) or shorter spines (sand dollars) . . . **Class Echinoidea** (sea urchins, sand dollars, etc.)

(4) Body ovoid; body wall muscular with small, scattered, internal calcareous plates; no spines; tentacles around mouth . . . **Class Holothurioidea** (sea cucumbers)

(5) Body cup-shaped; 5 arms branched with featherlike pinnules; stalk for attachment . . . **Class Crinoidea** (sea lilies, feather stars)

BB. Bilateral symmetry

C. Body flat, soft, wormlike . . . **Phylum Platyhelminthes** (flatworms)

(1) Free-living; body covered with cilia; usually no suckers; mouth and digestive tract but no anus . **Class Turbellaria** (planarians)

(2) Parasitic; no cilia in adult; mouth and enteron but no anus; 1 or more suckers . . . **Class Trematoda** (flukes)

Continued on next page.

(3) Parasitic; no cilia in adult; no ventral suckers, but may be suckers on scolex; no mouth, digestive tract, or anus; tapelike series of proglottids or individuals	**Class Cestoda** (tapeworms)
CC. Body cylindrical (or slightly flattened), soft	**Phylum Aschelminthes (Nemathelminthes)** (cavity worms or roundworms)
(1) No cilia on external surface	**Class Nematoda** (Parascaris [Ascaris], pinworms, Filaria, Trichina, hookworms, etc.)
(2) Cilia on head rotate like wheel; chitinous jaws (mastax) grind foods; tail-like foot often forked .	**Class Rotifera** (rotifers)
CCC. Body soft, not wormlike; usually larger types than C and CC; many with external, calcareous shells; usually a ventral, muscular foot	**Phylum Mollusca** (mollusks)
(1) Bilateral symmetry conspicuous; shell of 8 dorsal calcareous plates	**Class Amphineura** (chitons)
(2) Muscular foot with distinct head containing eyes, and 1 or 2 pairs of tentacles; radula present for rasping foods; usually spirally coiled, asymmetrical calcareous shell	**Class Gastropoda** (snails, slugs, whelks, etc.)
(3) Body enclosed in hollow, toothlike shell, open at either end	**Class Scaphopoda** (tooth shells)
(4) Head and foot fused into a "head-foot," with 8 to 10 tentacles around mouth; eyes and radula; tubular siphon for circulating water; shell may be absent, greatly reduced and internal, or external and chambered	**Class Cephalopoda** (squids, octopi, nautili, etc.)
(5) Foot hatchet-shaped for burrowing; no head, tentacles, eyes, or radula; membranous mantle secretes bivalved, calcareous shell	**Class Pelecypoda** (clams, oysters, scallops, shipworms, etc.)
AA. Segmented (metameric) animals; bilateral symmetry	
B. Appendages not jointed; body wormlike	**Phylum Annelida** (segmented worms)
(1) Bristlelike setae arranged in pits on body segments; bandlike clitellum around body for copulation purposes	**Class Oligochaeta** (earthworms)
(2) Paired paddlelike parapodia which contain numerous setae on body segments; distinct head with eyes, tentacles, and fingerlike sensory palps; no clitellum .	**Class Polychaeta** (sandworms)

(3) Body flattened; body segments usually 34, each of which divided into several false segments; no head, tentacles, setae, or parapodia; anterior and posterior suckers . . . . **Class Hirudinea** (leeches)

BB. Appendages jointed (usually)

C. External chitinous skeleton; no internal skeletal axis . **Phylum Arthropoda** (arthropods)

(1) Aquatic; gill-breathing; head with 2 pairs of antennae; usually at least 5 pairs of jointed appendages . . . . **Class Crustacea** (crayfishes, lobsters, barnacles, crabs, water fleas, etc.)

(2) Terrestrial; trachea-breathing; head with 1 pair of antennae; long dorsoventrally flattened body of 15 or more segments, most of which bear 1 pair of jointed appendages . . . . **Class Chilopoda** (centipedes)

(3) As (2) above, but with 2 pairs of jointed appendages per body segment . . . . **Class Diplopoda** (millipedes)

(4) Terrestrial; trachea-breathing; head with 1 pair of antennae; body divided into head, thorax, and abdomen; thorax with 3 pairs of jointed legs and usually 1 or 2 pairs of wings (in adult); several types wingless . . . . **Class Insecta** (insects)

(5) Terrestrial; usually trachea-breathing or by book lungs (gills for aquatic types); no antennae; no true jaws, first mouth appendages being nippers (chelicerae); no wings; body divided into cephalothorax (head-thorax) and abdomen; 4 pairs of jointed walking legs . . . . **Class Arachnoidea** (spiders, scorpions, mites, ticks, harvestmen, king "crabs," etc.)

CC. Dorsal, internal skeletal axis; dorsal notochord may be temporary or permanent; dorsal, central nervous system; paired pharyngeal clefts ("gill slits") in pharyngeal region (at some stage in life cycle) . **Phylum Chordata** (chordates)

D. Wormlike animal; 3 body regions (proboscis, collar, and trunk); dorsal notochord in proboscis only; all marine types . . . . **Subphylum Hemichordata** (Balanglossus, Dolichoglossus, etc.)

DD. Saclike animal; adult sessile; enclosed by tunic of cellulose; notochord absent in adult but present in tail of tadpolelike larva; all marine . . **Subphylum Urochordata** (sea squirts, tunicates, such as Molgula)

DDD. Fishlike animal; free swimming; numerous V-shaped muscles along body; without distinct head or paired appendages; persistent noto-

Continued on next page.

chord along entire length of body; 100 pairs of pharyngeal clefts; all marine types . . . **Subphylum Cephalochordata** (Amphioxus)

DDDD. Axial dorsal notochord of embryo replaced by series of vertebrae; 2 pairs of jointed appendages present (usually); brain case (cranium) present . . . . **Subphylum Vertebrata** (vertebrates)

(1) Eel-like animal without jaws or paired fins; 7 or more pairs of pharyngeal clefts; notochord persists as skeleton; circular mouth . . . . **Class Cyclostomata (Agnatha)** (lampreys, hagfishes, etc.)

(2) Fishlike animal with paired jaws and paired fins; vascular gills supported by cartilaginous gill plates; persistent notochord and cartilaginous skeleton; ventral mouth; placoid (toothlike) scales of enamel-like material; 2-chambered heart; cold blooded (temperature varies with surroundings) . . . . **Class Elasmobranchii (Chondrichthyes)** (sharks, rays)

(3) Fishlike animal with paired jaws; mouth terminal; usually lateral fins with fin rays; gills covered with operculum (gill cover); skeleton completely or partially bony; scales dermal (not placoid); 2-chambered heart; cold blooded . . . . **Class Pisces (Osteichthyes)** (bony fishes)

(4) Paired jaws; usually 2 pairs of 5-toed limbs, without claws (some legless); webbed feet often present; gills in embryo and lungs in adult; skeleton mostly bony; skin moist and smooth; no external scales; 3-chambered heart; cold blooded **Class Amphibia** (frogs, toads, salamanders, etc.)

(5) Horny epidermal scales or bony dermal plates; paired limbs, usually with 5 toes with claws (snakes without paired appendages); lungs in both embryo and adult; skeleton well ossified; 3-chambered heart (4-chambered in higher types); cold blooded . . . . **Class Reptilia** (turtles, snakes, lizards, crocodiles, etc.)

(6) Body usually spindle-shaped and covered with feathers (and scales on legs); wings for anterior appendages; skeleton fully ossified with air cavities; lungs in embryo and adult; 4-chambered heart; warm blooded (temperature remains rather constant regardless of external temperature) . . . . **Class Aves** (birds)

(7) Hair on body (reduced on some, and in certain places); mammary glands to suckle young; diaphragm separates thorax and abdomen; lungs in embryo and adult; voice apparatus consisting of larynx and epiglottis; 4-chambered heart; warm blooded . . . . **Class Mammalia** (mammals such as man, cat, dog, horse, whale, bat, etc.)

Appendix 3

Materials and solutions needed for various exercises

Use of scientific method

1. Yardstick for measuring height of students

Preliminary microscopic work

1. Prepared slide of letter "L" (or similar preparation)
2. Prepared slide of colored threads (or similar preparation)
3. Different types of microscopes, such as binocular microscopes, projection microscopes, etc.

Early history and development of natural science

1. References (history of science, encyclopedias, etc.)
2. Articles showing how biologists have solved problems
3. Pictures of biologists (for opaque projection)
4. Lantern slides and movies

Molecular and cellular biology

1. Models, charts, projected slides of atoms and molecules, especially as they pertain to living protoplasm
2. Prepared slide of *Necturus* liver (or similar preparation)
3. Prepared slide of *Spirogyra* (green alga plant) (showing conjugation) (or similar preparation)
4. Living culture of *Spirogyra* (or similar preparation)
5. Iodine solution
6. Additional plant and animal cells
7. Photographs of microscopic structures of cells (from magazines, texts, etc.)

Physical properties and chemical composition of protoplasm

1. Fresh-water plant *Elodea (Anacharis)*
2. Culture of living amebas
3. Grape sugar (glucose) solution
4. Benedict's reagent for test for sugar. (Dissolve 173 grams of crystalline sodium citrate and 100 grams of sodium carbonate [anhydrous] in 800 ml. of distilled water. Filter and add, slowly with constant stirring, 17.3 grams of copper sulfate dissolved in 100 ml. of distilled water. Add sufficient distilled water to make 1 liter [1,000 ml.].)
5. Water bath (beaker of boiling water)
6. Starch solution
7. Iodine reagent for test for starch. (Dissolve 2 grams of potassium iodine [KI] in 100 ml. of distilled water and add iodine crystals until a deep brown color results.)
8. Lard (or other fatty or oily material)
9. Alcoholic solution of Sudan IV for test for fat: Saturated solution of the dye Sudan IV in absolute alcohol, and filtered
10. Brown paper
11. Albumin (protein) such as egg white (fresh or powdered)

12. Concentrated nitric acid
13. Strong ammonium hydroxide
14. Test materials such as potato, apple, bean, meat, nut, bread, etc.
15. Clean test tubes which withstand heating
16. Bunsen burners, or alcohol lamps

Activities of living protoplasm

1. Yeast culture (Break a cake of yeast [fresh, living] into 500 ml. of water to which has been added 10 grams of grape sugar [glucose]; cup of table sugar [sucrose] may be substituted.)
2. Two fermentation tubes (Smith type)
3. Flask (250 ml.) with one-hole rubber stopper and L-shaped glass tubing to show fermentation
4. Flask (150 ml.) with one-hole rubber stopper and L-shaped glass tubing for the barium hydroxide solution
5. Rubber tubing to connect above glass tubing
6. Barium hydroxide solution for testing for carbon dioxide (Add barium hydroxide to distilled water until no more will go into solution. Filter and keep in a tightly stoppered bottle.)
7. Sterile, heavy filter paper in a sterile Petri dish
8. Radish seeds (viable)
9. Rather large onion which fits on top of a beaker of proper size
10. Anesthetized frog for ciliated epithelial cells from roof of mouth
11. Salt solution (0.7% in distilled water)
12. Gill of living clam (instead of frog epithelium?)
13. Anesthetized frog on a frog mounting board to show blood flow (the gills of a living salamander may be substituted)
14. Suspension of a powdered dye such as carmine (colored chalk may be substituted)
15. Living sensitive plant *(Mimosa)*
16. Clean needle, forceps, and scissors, matches, flashlight, alcohol, distilled water
17. Pithed frog to supply gastrocnemius muscle with sciatic nerve attached
18. Dry cell battery and electrodes
19. Several living planarians *(Dugesia)* to demonstrate regeneration
20. Clean watch glasses containing pond water and with proper covers
21. Clean square cover glasses for cutting planarians

Plant kingdom—major groups of plants

1. Labeled specimens of algae, fungi, thalloid liverworts, leafy liverworts, true mosses, club "mosses," horsetails, ferns, gymnospermous plants, and angiospermous (flowering) plants
2. Identification keys, museum materials, photographs of major groups of plants

Cellular organization of plants (tissues and organs)

1. Prepared slides of plant tissues:
   a. Epidermal (or fresh plant leaves)
   b. Parenchyma (pith of corn stem, or similar material)
   c. Sclerenchyma (corn stem, fresh celery or plantain materials; and hulls of nuts, gritty masses of pears, or fresh materials)
   d. Xylem
      (1) Tracheids (stem of pine tree)
      (2) Vessels (stem of corn)
   e. Phloem
      (1) Sieve tubes (stem of corn)
      (2) Phloem parenchyma (stem of corn)

f. Meristematic (root tips of onion *[Allium]* or spiderwort *[Tradescantia]*, or similar material)

Mitotic cell division (mitosis) in plants

1. Prepared stained slide of onion root *(Allium)*, spiderwort *(Tradescantia)*, or similar plant tissue
2. Models, charts, projected materials, showing plant mitosis

Meiotic cell division (meiosis) in plants

1. Prepared stained slides showing meiosis in the anther of the lily (or similar plant)
2. Models, charts, projected materials, showing meiosis in plant cells

Simple plants with chlorophyll—algae

1. Preserved materials, living specimens, and prepared slides of
   a. *Gleocapsa*
   b. *Oscillatoria*
   c. *Nostoc*
   d. *Euglena*
   e. *Chlamydomonas*
   f. *Protococcus*
   g. *Spirogyra*
   h. *Ulothrix*
   i. Desmids
   j. *Volvox*
   k. Volvocine series of green algae
      (1) *Chlamydomonas*
      (2) *Gonium sociale*
      (3) *Gonium pectorale*
      (4) *Pandorina morum*
      (5) *Eudorina elegans*
      (6) *Pleodorina illinoisensis*
      (7) *Pleodorina californica*
      (8) *Volvox perglobator*
   l. Diatoms and diatomaceous earth
   m. *Vaucheria*
   n. The kelp *(Laminaria)*
   o. Rockweed *(Fucus)*
   p. *Nemalion*
   q. *Polysiphonia*

Simple plants without chlorophyll—fungi (bacteria—fission fungi)

1. Four sterile Petri dishes containing agar medium (which has been autoclaved)
2. Glass-marking pencil
3. Clean forceps and Bunsen burner (or alcohol lamp)
4. Coin of money
5. Tubes of agar medium with plugs which have been autoclaved and slanted before cooling
6. Inoculating needles
7. Agar plates inoculated with bacteria and on which disks of antibiotics (and sulfa drugs) have been placed to demonstrate their effectiveness
8. Stained slides of bacteria (or projected slides, charts, demonstration slides using oil immersion objective)
   a. Coccus types

b. Rod-shaped types
c. Spiral types
d. Bacteria with spores
e. Bacteria with flagella
f. Bacteria dividing by fission
g. "Hanging drop" of living *Escherichia coli* to demonstrate locomotion (oil immersion objective)

9. Living culture of *Escherichia coli* (intestinal organism)
10. Two fermentation tubes (Dunham type) (small test tubes inverted in larger ones) containing sterile 1% lactose (sugar) broth medium
11. Indicator paper (litmus, or similar type to determine pH)
12. Two tubes of sterile gelatin medium
13. Living culture of *Proteus vulgaris*
14. Cold water or ice in beaker
15. Demonstration materials to show beneficial and detrimental effects of bacteria

Simple plants without chlorophyll—fungi (slime fungi and true fungi)

1. Preserved materials, living specimens, prepared slides, and projected slides of:
   a. *Stemonitis*
   b. *Lycogala*
   c. *Physarum*
   d. Black bread mold *(Rhizopus)*
   e. Water mold *(Saprolegnia)*
   f. *Penicillium*
   g. Cup fungus *(Peziza)*
   h. Bread yeast *(Saccharomyces)*
   i. Mushrooms
   j. Bracket (shelf) fungus
   k. Black stem rust of wheat (including life cycle mounts, charts, slides, etc.)

Intermediate plants with chloroplasts—bryophytes (liverworts and true mosses)

1. Preserved materials, living specimens, prepared slides, and projected slides of:
   a. Thalloid liverworts *(Marchantia)*
   b. Leafy liverworts *(Porella)*
   c. Hairy-cap moss *(Polytrichum)*
   d. Peat moss *(Sphagnum)*

Higher plants with true leaves, stems and roots (club "mosses," horsetails, and ferns)

1. Preserved materials, living specimens, prepared slides, and projected slides of:
   a. Club "moss" *(Lycopodium)*
   b. Small club "moss" *(Selaginella)*
   c. Horsetail *(Equisetum)*
   d. Bracken fern *(Pteridium)*
   e. Polypody fern *(Polypodium)*

Higher plants with exposed (naked) seeds—gymnospermous plants

1. Preserved materials, living specimens, prepared slides, and projected slides of
   a. Pine tree *(Pinus)*

Higher plants with enclosed seeds—angiospermous (flowering) plants

1. Preserved materials, living specimens, prepared slides, and projected slides of
   a. Garden bean *(Phaseolus)*, plant, flower, and pod
   b. Buttercup *(Ranunculus)* flowers

c. Sunflower *(Helianthus)* flowers, prepared slides of mature stem (cross section), prepared slide of mature root (cross section)
d. Indian corn *(Zea mays)*, slide of stem (cross section), slide of leaf (cross section), male and female flowers, fruit (kernel, "seed")

Biology of higher plants

1. Living and preserved specimens, museum materials, prepared slides, charts, models, lantern slides, pictures for opaque projection, movies of higher plants, and various pertinent demonstrations for
   a. Roots
   b. Stems
   c. Leaves
   d. Flowers and reproductive organs
   e. Fruits and seeds
   f. Materials to show absorption and translocation of materials
   g. Materials to show transpiration and guttation
   h. Demonstration of food manufacture and storage
   i. Demonstration of respiration and digestion
   j. Demonstration of abscission
   k. Various plants of economic importance, including products which they supply

Kinds of fruits

1. Preserved and fresh materials
   a. Simple fruits
      (1) Dry fruits
         (a) Dehiscent fruits
            (i) Legume (string bean, lima bean, pea, locust tree, peanut, etc.)
            (ii) Follicle (milkweed, larkspur, peony, spiraea, columbine, etc.)
            (iii) Capsule (iris, lily, tulip, poppy, pansy, horse chestnut, snapdragon, violet, etc.)
         (b) Indehiscent fruits
            (iv) Achene (sunflower, buttercup, buckwheat, dandelion, etc.)
            (v) Grain or caryopsis (corn, wheat, oats, barley, rice, grasses, etc.)
            (vi) Samara or key or wing fruit (elm tree, ash tree, basswood tree, maple tree, etc.)
            (vii) True nut (filbert, or hazlenut, beechnut, acorn of oak trees, chestnut, hickory nut, etc.)
      (2) Fleshy fruits
            (i) True berry (tomato, grape, date, avocado, red pepper, citrus fruits such as orange, lemon, grapefruit, etc.)
            (ii) False berry (cucumber, pumpkin, watermelon, gourd, cantaloupe, cranberry, banana, etc.)
            (iii) Drupe or "Stone fruit" (olive, apricot, coconut, peach, plum, cherry, almond, etc.)
            (iv) Pome (apple, pear, quince, hawthorn [haw], etc.)
   b. Aggregate fruits (raspberry, boysenberry, blackberry, strawberry, etc.)
   c. Multiple (compound) fruits (pineapple, Osage orange ["Hedge apple"], mulberry, fig, etc.)

Animal kingdom—major groups of animals

1. Labeled specimens of such animals as protozoans, Porifera, coelenterates, ctenophorans, Platyhelminthes (flatworms), Aschelminthes (Nemathelminthes) (roundworms), mollusks, echinoderms, annelids, arthropods, chordates (lower and higher)

Cellular organization of animals (organs and tissues)

1. Prepared slides of the following tissues:
   a. Epithelial
      (1) Squamous (pavement)
      (2) Columnar
   b. Connective (supportive)
      (1) Areolar
      (2) Adipose
      (3) Hyaline cartilage
      (4) Bone
   c. Blood (vascular)
      (1) Human and frog
   d. Muscular (contractile)
      (1) Skeletal (striated)
      (2) Visceral (unstriated or smooth)
   e. Nervous
      (1) Golgi preparation of neurons (nerve cells)

Mitotic cell division (mitosis) in animals

1. Prepared slide of the blastula stage of the whitefish embryo (or similar cells)
2. Models, projected slides, photos, etc.

Meiotic cell division (meiosis) in animals

1. Prepared slide of a thin section of the female reproductive system of the roundworm, *Parascaris* (ascaris), (or similar animal cells)
2. Demonstration materials, color transparencies, models, charts, illustrations, etc.

Unicellular (acellular) animals—protozoa

1. Living specimens, preserved materials, prepared slides, projected slides, and life cycles of
   a. *Amoeba*
   b. *Peranema*
   c. *Noctiluca*
   d. *Paramecium*
   e. *Plasmodium*
   f. *Monocystis*
2. Yeast mixture—Congo red for feeding living paramecia (In 10 ml. of distilled water mix 3 grams of compressed yeast and 0.03 gram of Congo red [dye]. Boil for 10 minutes over gentle heat. Cool and keep stoppered in a bottle in a refrigerator. Shake well before using, and dispense with a pipette or tooth pick to the culture on the slide before adding the cover slip. Examine quickly. **Do not add too much of the yeast mixture-Congo red.** Yeast cells in the food vacuoles are first blue, later an orange-red.)
3. Living paramecia (mating types A and B of *P. bursaria*)
4. Methyl green (dilute solution) to discharge trichocysts
5. Clean, 3-depression, concave slides and clean pipettes
6. Living earthworm
7. 7% alcohol, or 5% chloretone
8. 0.75% solution of sodium chloride
9. Binocular microscopes

Sponges, coelenterates, and ctenophorans

1. Preserved specimens, prepared slides, projected slides, and museum preparations of:
   a. *Scypha (Grantia)*

b. Slides of spicules of *Scypha*
c. Venus's flower basket *(Euplectella)* skeleton
d. Commercial (bath) sponge (preserved)
e. Prepared slide of spongin fibers
f. *Hydra* (living and preserved)
g. Brine shrimps for feeding living hydra, and clean concave slides
h. *Daphnia* (a crustacean) for feeding living hydra, and clean concave slides
i. Infra-red light, ice cubes, salt, acetic acid, dissecting needle, strong magnet, etc., for observing behavior of hydras
j. *Obelia* (hydroid and medusoid stages)
k. *Gonionemus*
l. Sea anemone
m. Corals
n. A ctenophoran *(Pleurobrachia)* or similar organism

Flatworms

1. Preserved materials, living specimens, prepared slides, projected slides, museum preparations, and life cycles of
   a. *Dugesia (Planaria)*
   b. Oriental liver fluke *(Clonorchis)*, including stages of life cycle
   c. Sheep liver fluke *(Fasciola hepatica)*, including stages of life cycle
   d. Tapeworm (scolex and proglottids)

Roundworms or "cavity worms"

1. Preserved materials, living specimens, prepared slides, projected slides, museum preparations, and life cycles of
   a. *Parascaris equorum (Ascaris megalocephala)*, preserved male and female
   b. Prepared stained slide of cross section of ascaris
   c. Hookworms (preserved and prepared slides of male and female)
   d. Trichina (pork) roundworm *(Trichinella)* (prepared slide of cysts in muscles)
   e. Rotifers (preserved and living culture), including culture medium composed of sterile, distilled water and nonfat dried milk powder (1 gram in 1 liter of sterile, distilled water)

Segmented worms

1. Preserved materials, living specimens, prepared slides, projected slides, museum preparations, and life cycles of
   a. Earthworm *(Lumbricus)*, including cocoons
   b. Prepared stained slide of cross section of earthworm
   c. Leeches (preserved and living)

Animals with soft bodies and hard shells—mollusks

1. Preserved materials, living specimens, prepared slides, projected slides, museum preparations, and life cycles of
   a. Clams
   b. Snails
   c. Squids

Animals with spiny skins—echinoderms

1. Preserved materials, prepared slides, projected slides, museum preparations, and life cycles of
   a. Starfish, including one with water-vascular system injected
   b. Sea urchin *(Arbacia)*
   c. Additional miscellaneous echinoderms

Animals with jointed appendages and an exoskeleton of chitin—arthropods

A. *Survey of the classes of the phylum Arthropoda*
   1. Crustaceans such as crayfish, lobster, shrimp, crab, barnacle, etc.
   2. Centipedes
   3. Millipedes
   4. Insects such as beetles, moths, butterflies, flies, grasshoppers, bees, etc.
   5. Arachnids such as spiders, scorpions, horseshoe "crabs," mites, etc.

Animals with jointed appendages and an exoskeleton of chitin—arthropods (cont'd)

B. *Economic entomology—economic insects*
   1. Preserved insects in mounts
      a. Beneficial insects
      b. Parasitic insects
      c. Insects injurious to stored grains
      d. Insects affecting grasses, grains, and forage crops
      e. Insects injurious to corn
      f. Insects affecting potatoes and tomatoes
      g. Insects affecting beans and peas
      h. Insects affecting fruits
      i. Insects affecting homes

Animals with jointed appendages and an exoskeleton of chitin—arthropods (cont'd)

C. *Common insects—grasshopper and honeybee*
   1. Preserved materials of
      a. Grasshopper *(Romalea)* (adults and larval stages)
      b. Honeybee *(Apis)* worker
   2. Museum preparation of the castes of honeybee
   3. Prepared slides of insects structures and parts
   4. Examples of the types of insect metamorphosis

Animals with jointed appendages and an exoskeleton of chitin—arthropods (cont'd)

D. *Identification and classification of insects*
   1. Mounted insects of the various orders to be identified by means of the key

Lower chordates—protochordates

   1. Specimens of
      a. *Glossobalanus (Balanoglossus)*
      b. *Sacchoglossus (Dolichoglossus)*
      c. Sea squirt or tunicate *(Molgula)*
      d. *Amphioxus (Branchiostoma)*
      e. Additional representative protochordates

Vertebrates

   1. Preserved specimens of
      a. Lampreys and hagfishes
      b. Sharks and rays
      c. Bony fishes, eels, etc.
      d. Frogs, toads, salamanders
      e. Turtles, lizards, snakes, chameleons, etc.
      f. Birds
      g. Mammals such as cats, pigs, rats, bats, hamsters, etc.
   2. Skeletons of as many of the above as desirable
   3. Demonstration materials of certain systems of the above

Frog—an amphibious vertebrate animal

1. Preserved or fresh frog for dissection
2. Mounted skeleton of frog (and disarticulated bones of frog)
3. Demonstration skeleton of bullfrog
4. Models of frog, frog brain, etc.
5. Charts, projected slides of frog
6. Frog with circulatory system injected (for demonstration)

Pig—a mammalian vertebrate animal

1. Preserved fetal pig for dissection
2. Mounted skeleton of pig (or of cat or similar mammal)
3. Human skeleton (for comparison and contrast purposes)
4. Models of mammals to explain certain structures
5. Charts, projected slides of mammalian structures and functions
6. Fresh and/or preserved organs such as heart, kidneys, eyes, etc., of pig, beef, etc.
7. Pig with circulatory system injected (for demonstration)

Biology of man

1. Models, charts, human skeleton, museum preparations, film strips, lantern slides, movies, pertinent demonstration materials, etc.

Living plants and animals contrasted

1. Various samples of water from a small pond, a lake, several types of streams, each properly labeled in clean bottles
2. Nets and other collecting equipment
3. Selected references (especially with illustrations) for identifying aquatic plants and animals
4. Binocular microscopes with watch glasses

Additional biochemical and biophysical phenomena in plants and animals

1. Permeability of membranes and osmotic pressure
   a. Permeable membrane (such as piece of bladder or similar membrane)
   b. Thistle tube with string and cement
   c. Medicine dropper with small bore
   d. Clamp and stand
   e. 20% aqueous solution of sugar and a beaker of distilled water
   f. Fresh egg
   g. Beaker of water with ring stand to support egg in the water
   h. Fresh red beet
   i. 3 clean Petri dishes
   j. 10% salt solution
   k. Boiling water
   l. Dialysis tubing to make a bag about 10 cm. long, and string for tying
   m. Soluble starch solution
   n. Iodine solution
2. Plasmolysis
   a. Fresh water plant *(Elodea)* leaves (several living)
   b. 5% aqueous solution of sodium chloride
   c. Living *Spirogyra* filaments
   d. 15% aqueous solution of sugar
   e. Strips of filter paper
   f. Several leaves of the plant *Rhoeo discolor* ("Babes in a Cradle" or "Moses in the Bulrushes")
   g. 10% salt solution

3. Diffusion
   a. Two beakers of same capacity
   b. Source of heat such as a lamp, radiator, etc.
   c. Crystals of potassium permanganate (of equal sizes)
4. Conduction (transportation)
   a. "Stalk" of celery (fresh)
   b. Large pan of water to immerse the celery entirely
   c. Weak aqueous solution of a dye (safranin or eosin) or red ink
   d. Stems of such plants as *Coleus*, young corn plants, or similar elongated sections of a fresh potato
   e. Living earthworm (preferably of small size)
   f. Cardboard with long hole to accommodate this sized earthworm
   g. Rubber bands
   h. Binocular microscope
5. Transpiration in plants
   a. Two similar well-watered plants in pots
   b. Aluminum foil (or wax paper or rubber sheet)
   c. String and adhesive for tying above
   d. Balance for weighing potted plants
   e. Leaf with long petiole of a vigorously growing plant
   f. Cardboard with a hole in center just large enough to accommodate the petiole
   g. Two beakers of approximately the same size
6. Respiration
   a. Bromthymol blue indicator
   b. 4 clean test tubes of same size
   c. 3 brass screws with heads
   d. 8 germinating peas
   e. Boiling water
   f. Stoppers to fit test tubes tightly
   g. 2 pieces of clean glass tubing, or soda straws
   h. Clear lime water, $Ca(OH)_2$, in a test tube
7. Photosynthesis and light energy
   a. Geranium plants which have been kept in dark for 24 hours before experiment
   b. Light screens to attach to geranium leaves
   c. Several 150-watt reflecting (photography) bulbs
   d. Iodine reagent for testing for starch
   e. Alcohol to be boiled over an electric hot plate and in a water bath
   f. Several leaves of the plant, variegated *Coleus* (actively growing and fresh)
   g. Boiling water
   h. Several watch glasses
   i. 4 glass jars with tightly fitting tops (about ½ pint capacity)
   j. 4 geranium leaves with long petioles (3 green leaves, and 1 variegated, or white) (plants have been kept in dark for 24 hours previous to experiment)
   k. 4 small vials to be placed in the jars
   l. 5% sodium acid carbonate, $NaHCO_3$, solution
   m. 10% sodium hydroxide, NaOH, solution
   n. Glass-marking pencil to label jars
   o. Clean glass tubing about 15 inches long and stoppers to fit tightly
   p. Culture of living *Euglena*
   q. Black paper or cloth
   r. 10% methyl cellulose (or an anesthetic such as 5% chloretone)
8. Bioluminescence and light

a. Such materials as display luminescence (firefly [beetle], glow-worm [larva of a beetle], certain jelly fishes such as *Pelagia*, such protozoans as *Noctiluca*, certain squids, and fishes, etc.)
b. Living culture of luminescent bacteria *(Photobacterium fischerii)*
c. Models, charts, projected slides, museum specimens, eyes of such organisms as mollusks, insects, crustaceans, frogs, mammals, and man

9. Plant colorations
a. Several leaves of fresh spinach and a beaker of boiling water
b. Paper towels or filter paper
c. Alcohol warmed in a water bath on an electric hot plate
d. Clean pipette
e. Two clean test tubes
f. Benzene
g. Piece of filter paper (5 x 6 inches) and paper clip or pin
h. 1 fine capillary pipette
i. Sealed jar (6 inches high) with 1 inch of a mixture of 1 part petroleum ether and 1 part benzene (1 : 1 mixture)
j. Leaves of red cabbage (or similar source of anthocyanin pigment)
k. 500 ml. Erlenmeyer flask with sufficient distilled water to cover the cabbage leaves
l. Hot plate or Bunsen burner with tripod
m. 2 clean test tubes
n. Solution of potassium hydroxide (KOH), or similar base
o. Hydrochloric acid (HCl), or similar acid

10. Animal colorations
a. Prepared slides showing chromatophores
b. Tropical butterfly *(Morpho)*
c. Bird feathers to show colorations
d. Moths, butterflies, and vertebrates which show colorations

11. Production and reception of sound
a. Common locust
b. Cicada (male)
c. Mosquitoes (male and female)
d. Frog (or other animal) to demonstrate vocal apparatus and ear
e. Models and charts of human vocal apparatus and ear

12. Plant reactions due to hormones
a. Cuttings or "slips" of silver-leaf geranium, willow, or similar plant
b. Weak aqueous solution of indole-butyric acid (organic growth substance) and distilled water
c. 2 clean test tubes
d. Germinating oats plants showing the tubular coleoptile (or similar grass seedlings)
e. Sterile agar medium (3% and 1 mm. thick) in Petri dishes
f. Sterile scalpel or razor blade for cutting agar into squares and also for cutting coleoptiles from seedlings

13. Germination and viability of seeds
a. Corn kernels (3 lots)
b. Tetrazolium (Triphenyl tetrazolium chloride) reagent (sufficient strength to make a yellowish color) and which is kept in the refrigerator
c. Clean Petri dishes (one for each lot of kernels)
d. Clean scalpel or razor blade to bisect the corn embryo
e. Iodine solution to test for starch

14. Phenomena due to animal enzymes
a. 4 clean test tubes

b. 1% starch solution (corn starch) (1 gram of starch boiled in 100 ml. of distilled water) (prepared and filtered just before using)
c. Clean paraffin for securing saliva in clean beaker
d. Litmus paper (or other testing paper)
e. Iodine reagent for testing for starch
f. Solution of maltose (malt sugar) or glucose (grape sugar, dextrose)
g. Benedict's reagent for testing for sugar
h. Clean pipettes, sizes 1 ml., 5 ml., etc.
i. Fibrin (protein), or piece of boiled egg white
j. 4 clean test tubes
k. Solution of pepsin (2 grams of commercial pepsin in 100 ml. distilled water)
l. 0.2% hydrochloric acid (6 ml. of concentrated hydrochloric acid in 944 ml. of distilled water)
m. Corn oil (or similar liquid fat)
n. 2 clean test tubes
o. Pancreatic juice (5 grams of commercial pancreatin [pancreatic lipase enzyme]; 15 grams of sodium carbonate; 100 ml. distilled water)
p. Water bath (beaker of boiling water)

15. Blood typing
   a. Blood serum containing agglutinin (antibody) anti-A
   b. Blood serum containing agglutinin (antibody) anti-B
   c. Clean glass slides
   d. Glass-marking pencil
   e. Sterile lancet or sewing needle for drawing blood
   f. Alcohol for sterilizing finger
   g. Paper towels or blotting paper
   h. Clean toothpicks
   i. Blood serum containing anti-Rh
   j. Warming tray
16. Irritability, transmission (conduction) of excitation, and reactions (behaviors), in living organisms
   a. Small glass tube (rather small caliber) with 2 proper sized corks
   b. Culture of living *Euglena*
   c. Black paper or cloth
   d. Small glass tube with 2 proper sized corks
   e. Living paramecia, water flea *(Daphnia)*, fruit fly *(Drosophila)*, or other animals
   f. Living ameba
   g. Solution of sodium chloride
   h. Weak solution of acetic acid
   i. Living sensitive plant *(Mimosa)*
   j. Matches, alcohol, chemicals, flashlight, clean needle, etc. to stimulate *Mimosa*
   k. Living crayfishes in aquaria of sufficient size to permit locomotion
   l. Chemicals, light, magnet, tuning fork, etc. to stimulate crayfishes
   m. Carmine dye suspension and medicine dropper
   n. Demonstration specimen of appendage IV (mouth part, second maxilla) of crayfish
17. Tenacity of life (survival ability of plants and animals)
   a. Dried mud from creek or pond bottom
   b. Frozen soils
   c. Aquaria or glass dishes to contain soil and mud samples
   d. Sterilized, distilled water to add to aquaria
18. Electrolytic dissociation
   a. Electrolytic apparatus, including battery, wires, electrodes, etc.
   b. Solution of sodium chloride

Reproduction, embryonic development, and morphogenesis in plants and animals

1. Charts and illustrations showing continuity of protoplasm in successive generations
2. Charts, prepared slides, projected slides, illustrations, and museum preparations showing gametogenesis and sporogenesis in plants
3. Plant specimens, slides, museum specimens, charts, and illustrations showing embryonic development (embryogenesis) and differentiation and development of tissues and organs
4. Specimens, charts, illustrations, projected slides, museum preparations, showing the life cycle of a typical angiospermous (flowering) plant
5. Germinating garden beans
6. Germinating Indian corn
7. Prepared slides, preserved specimens, models, charts, museum preparations, projected slides, film strips, etc., of various stages of frog embryos (or similar animal)
8. Living eggs of frogs in aquarium
9. Demonstration slides of 72-hour and 96-hour chick embryo (prepared)
10. Demonstrations of 72-hour and 96-hour living chick embryos
11. Demonstration of materials in human embryology

Homology as shown by the segmental appendages of the crayfish

1. Preserved appendages of crayfish, either to be removed from crayfish or already removed and stored in labeled (or unlabeled) bottles.
2. Demonstration slides of the embryonic appendages of crayfish
3. Skeletons of frog, turtle, cat, bat, pig, man, etc., to illustrate homology
4. Various systems of the above animals to illustrate homology

Genetics (heredity) and variations in plants and animals

1. Demonstration slides of chromosomes to show as many details as possible
2. Microscope with oil immersion objective
3. Charts, illustrations, projected slides to show detailed structures of chromosomes
4. Coins for tossing experiments (2 alike such as pennies, and 2 others alike such a nickels or dimes)
5. Museum preparations of monohybrid crosses of garden peas
6. Museum preparations of dihybrid crosses of garden peas
7. Museum preparation of monohybrid and dihybrid crosses of Indian corn kernels showing colors, sugar or starch content, etc.
8. Additional plant materials showing heredity
9. Special seeds of sorghum, tobacco, soybeans, or other plant which show lethal (killing) genes in action (albinism)
10. Clean flower pots and clean garden soil or sand
11. Museum materials showing monohybrid, dihybrid, and trihybrid crosses in guinea pigs
12. Living fruit flies *(Drosophila)* (with vestigial wing inheritance)
13. Living fruit flies (with normal, long-wing inheritance)
14. Culture bottles for rearing fruit flies
15. Ether
16. Binocular microscope
17. *Drosophila* culture medium. Dissolve 15 grams of agar in 500 ml. of hot water; add ¾ gram of Dowicide A in 10 ml. of 95% ethyl alcohol (to inhibit mold growth); add 125 ml. molasses; add 110 grams of corn meal in 250 ml. of water. Mix well. Put a 1-inch layer into culture bottles (or half-pint milk bottles), stoppered with cotton plugs which are wrapped with cheesecloth. Allow to cool. Place a narrow strip of sterile stiff paper in each bottle to provide surface for pupation. Stopper the bottles and store in a refrigerator.

A few hours before use, inoculate the surface of the medium with brewer's yeast on which the flies will grow. Allow the bottles to warm to room temperature. Incubate at 37° C. (or room temperature if necessary). Transfers to fresh culture bottles should be made every 4 to 6 weeks in order to maintain healthy stocks. Student cultures may be kept in smaller vials.

18. Strips of paper impregnated with phenylthiocarbamide (PTC) (40 mg. in one liter of water).
19. 100 snail shells (or similar animal materials), illustrating variations
20. Metric ruler
21. 100 beans (or similar plant materials) illustrating variations
22. Numerous leaves all from the same plant to illustrate variations

Special problems in genetics

1. Demonstration materials to show sex-linked traits such as white and red eye colors in fruit flies
2. Demonstration materials to show sex-linked traits such as hair colors in cats (yellow, black, and tortoise-shell)
3. Demonstration materials to show sex-linked traits such as human color-blindness
4. Demonstration materials to show lethal genes, such as Creeper (short-legged) chickens
5. Demonstration materials to show multiple alleles such as hair color in rabbits (full color, chinchilla, Himalayan albino, and albino)
6. Demonstration of multiple alleles such as the inheritance of human blood groups (A, B, AB, and O)

Family traits—a study of your family

1. Selected human pedigrees to show the inheritance of certain traits
2. References on human heredity
3. Film strips and movies

Living organisms—their origins, continuity, and evolution

1. Museum materials (plant and animal) illustrating evolution
2. Casts, models, and charts showing evolution
3. Projected slides, film strips, movies, and pictures for opaque projection
4. Charts and other materials to show "continuity of life"

Animals and plants of the past and their records—paleontology

1. Museum materials showing various ways in which plants and animals have left records
2. Various types of plant and animal fossils
3. Models of early plants and animals (such as dinosaurs, etc.)
4. Film strips, projected slides, movies, magazine articles, etc.

Early man and his records

1. Casts, models, charts, projected slides, film strips, movies, pictures for opaque projection, selected references and pamphlets

Living organisms and their environments—ecology

1. Numerous clean, tightly stoppered collecting bottles with labels
2. Nets and other collecting equipment to secure samples (aquatic and terrestrial)
3. References (especially with illustrations) for identifying plants and animals
4. Thermometer (aquatic type)
5. Meter stick or measuring tape
6. Indicator paper

7. Spade (or trowel) for securing samples
8. Notebook for making maps, notes, etc.

Geographic distribution of plants and animals—biogeography

1. Museum preparations, charts, models, maps, projected slides, pictures for opaque projection, film strips, movies, selected references such as atlases, economic geographies, encyclopedias, natural histories, etc.

Unity, interrelationships, and similarities in the living world

1. Charts of the nitrogen cycle, carbon cycle, oxygen cycle, and sulfur cycle
2. Closely related species of animals, and closely related species of plants, to demonstrate certain similarities in structures and functions
3. Maps showing animal migrations and plant dispersals
4. Museum materials illustrating methods of plant dispersal

Special kinds of interrelationships among organisms

1. Museum materials (plant and animal) to illustrate (a) parasitism, (b) symbiosis and mutualism, (c) commensalism, (d) gregariousness, (e) predatism, (f) epiphytic plants, (g) saprophytes, etc.
2. Examples of biotic communities (associations) and populations
3. Examples of carnivorous (insectivorous) plants such as Venus's fly trap, pitcher plants, sun dew, etc.
4. Materials on viruses, including bacteriophages

Applied biology

1. Charts, atlases, encyclopedias, and selected references on foods, clothing, furniture, fuels, recreation equipment, medicines, and wealth
2. Charts, film strips, and movies on diseases of plants, animals, and human beings (caused by plants and animals)
3. Charts, pictures for opaque projection, film strips, movies, and selected references on water supplies, sewage disposal, garbage disposal, sanitation and health departments (city, county, state, and federal).

Genetic improvements of living organisms—plants, animals, and human beings

1. Charts, projected slides, film strips, movies, pictures for opaque projection, and selected references for plant and animal improvements by genetic methods
2. Museum materials on hybrid corn
3. Examples of domesticated animals improved by genetic methods
4. Examples of cultivated plants improved by genetic methods
5. Charts, film strips, movies, and selected references on human genetics

Diseases—immunity and defenses

1. Charts, film strips, movies, pictures for opaque projection, projected slides, and selected references on diseases of plants, animals, and human beings
2. Examples of toxins, antitoxins, etc.
3. Examples of sulfonamide ("sulfa") drugs
4. Examples of antibiotics including Diadisks for testing the efficiency of antibiotics for certain pathogenic bacteria
5. Charts, pictures, and selected references on allergies
6. Museum preparations of diseases of plants and animals caused by plants and animals

Conservation of resources—saving for ourselves and the future

1. Charts, models, film strips, projected slides, movies, pictures, and selected references for the conservation of various types of resources

2. Materials showing the conservation of human beings, including charts, projected slides, movies, selected references, etc.

National Parks

1. Maps, pictures for opaque projection, projected slides, movies, and selected references dealing with various National Parks and the resources for which each is particularly noted

Appendix 1

1. Labeled "unknown" plants to be identified by KEY

Appendix 2

1. Labeled "unknown" animals to be identified by KEY