LABORATORY EXERCISES

IN

ANATOMY AND PHYSIOLOGY

BY

JAMES EDWARD PEABODY, A.M.

Instructor in Biology in the
High School for Boys and Girls, New York City

NEW YORK
HENRY HOLT AND COMPANY
1898

ROBERT DRUMMOND, PRINTER, NEW YORK.

PREFACE.

Every pupil in the study of human physiology should be led to see that most of the materials required for observation and experiment in this subject are furnished by the organs and tissues of his own body. The following laboratory directions aim primarily to familiarize the pupil with the working of his own organs of motion, circulation, respiration, and digestion. Much of the necessary supplementary material (soup-bones, meat, foods, etc.) can be easily obtained by the student. The pieces of apparatus needed for the class demonstrations and experiments (test-tubes, bell-jars, thistle-tubes) are usually found in the chemical or physical laboratory of the school.

At the beginning of each topic of study I have given directions which in my experience have been found necessary to guide the pupil in his observations and experiments. The questions which follow these directions have been framed with the object of leading the student to seek the facts *from the material itself.* The student should be trained especially to distinguish in the experiments *observed results* from the *inferences* that may be drawn from those results.

I have found that a considerable amount of laboratory work may be most profitably done by the pupil at home and reported in class at the next recitation period. This is especially true in the study of foods, yeast, and bacteria. Iodine and Fehling solution are furnished the pupil and test-tubes are loaned. We have found that four fifths of the test-tubes are returned uninjured. In the pages that follow I have marked thus * the exercises adapted for home study. The mark † indicates a demonstration before the class by the teacher. The remaining exercises (unmarked) would best be performed by each pupil in the laboratory under the direction of the teacher.

The following method of recording the laboratory observations has been found to work successfully. The observations and conclusions are briefly recorded by the pupil in his note-book as the work is done. Some little time is taken for discussion at the close of the period, when the facts are clearest in mind, special care being taken to see that correct inferences have been drawn. That the work of the day may be more firmly fixed in the mind of the pupil he is required to write on paper of a certain kind and size and present at the next lesson a carefully prepared statement of (1) the steps in the experiment, (2) the results observed, (3) the conclusions which were drawn from the experiment. These papers, together with the drawings and other work prepared in class, are arranged in a cover belonging to each pupil, and constitute his laboratory book.

The descriptive terms dorsal and ventral, anterior and posterior, median and lateral, employed in comparative anatomy, are used in the following directions, since they seem preferable to the more indefinite terms front and back, upper and lower, middle and side, commonly used in books on human physiology. I have adopted throughout the food study the term nutrients (for food-materials, food-stuffs), and nitrogenous substances (for proteids, albuminoids, gelatinoids, etc.); these terms are used in the publications of the U. S. Department of Agriculture.

I have found the study of the material at the American Museum of Natural History (especially the skeletons and teeth of mammals) a valuable means of review and of awakening interest in the subject. With a definite list of questions (see p. 73) in the hands of each pupil a division of thirty to fifty can be directed in this work. Time should be taken at the close of such study for a comparison of notes and for general discussion.

Some knowledge of the cell is so essential to any intelligent comprehension of the subject of human physiology that it seems necessary to introduce frequent discussions of protoplasm and its properties. Circulating protoplasm is easily demonstrated in the cells of the plant Nitella. Epithelium (including gland and ciliated), muscle and nerve cells should be shown if possible. The study of yeast and bacteria is suggested to give the pupil some acquaintance with the physiology of the cell, as well as a knowledge of these organisms.

Since physiology unfortunately precedes physics and chemistry in the ordinary High School courses of study, it is necessary to give the pupil some idea of the fundamental principles of these subjects. It seems wise to discuss oxidation and its products more or less thoroughly. The structure and physiology of the organs of special sense (eye, ear), as well as the thorough consideration of levers, should be omitted, in my judgment, until after a course in physics has been taken.

It is not expected that all of the following experiments will be performed in the limited time usually assigned in the curriculum to this subject. The exercises are, however, sufficiently varied to allow a wide range of choice. The laboratory work on a given topic should if possible be given before the study of that topic in the text-book.

The teacher will find the following reference-books to be valuable in experimental physiology: Stirling's "Outlines of Practical Physiology," (P. Blakiston, Son & Co., Philadelphia); Foster and Langley's "Practical Physiology" (The Macmillan Co., N. Y.); Klein's "Micro-Organisms and Disease" (The Macmillan Co., N. Y.). Additional exercises are suggested in "Outlines of Requirements in Anatomy, Physiology, and Hygiene" (Harvard University).

Suggestions for many of the following exercises were found in the publications of J. Y. Bergen, B. P. Colton, H. Newell Martin, H. P. Bowditch, M.D., and in the books mentioned above. The outline for the study of bacteria was suggested by Dr. T. M. Prudden, College of Physicians and Surgeons, N. Y. The experiments with the joint apparatus (8) were adapted from the "Harvard Requirements," by Dr. G. W. Fitz of Harvard University, who devised the apparatus. Many valuable suggestions have been given by Dr. C. B. Davenport of Harvard University.

I am especially indebted to Dr. Margaret B. Wilson of the N. Y. Normal College for carefully revising my manuscript.

J. E. P.

HIGH SCHOOL FOR BOYS AND GIRLS,
NEW YORK CITY, July 13, 1898.

TABLE OF CONTENTS.

I. The Skeleton and Muscles.

LABORATORY EXERCISES

IN

ANATOMY AND PHYSIOLOGY.

1. STRUCTURE OF BONES.

Materials: A clean rib of lamb or pork cut smoothly across the end; two clean soup-bones, one sectioned transversely, the other divided into halves lengthwise. (After completing the study of the structure, lay aside the bones for the experiments in 2.)

A. Structure of a soup-bone (long bone).

1. Study of cross-section of a long bone.
   - *a.* In what respects is the layer of bone-tissue which covers the outside distinguishable from the tissues within?
   - *b.* How is the bone-tissue arranged within this outside layer?
   - *c.* What is the consistency of the marrow which fills the spaces in the bone-tissue?
   - *d.* How does the color of the marrow in the marrow-cavity differ from the color of the spongy bone? Can you suggest any reason for this difference?
   - *e.* Make a diagrammatic drawing of the cross-section of the bone magnified twice (× 2), labelling hard bone, spongy bone, marrow.

2. Study of longitudinal section of a long bone.
   a. Identify all the structures seen in cross-section, viz., hard bone, spongy bone, marrow.
   b. What additional facts in regard to the structure of a long bone do you learn from the longitudinal section?
   c. Make a drawing of the longitudinal section, labelling as in the previous drawing.

B. Structure of a rib (tabular bone).
   1. Can you distinguish in the cross-section of the rib the hard bone, spongy bone, and marrow?
   2. How do long bones and tabular bones differ in plan of structure?
   3. Make a diagrammatic drawing of the cross-section of the rib (× 2), labelling all the parts.

2. Composition of Bones.*

Materials: Two clean ribs; the two halves of the soup-bone used in 1; diluted hydrochloric acid (6 parts water to 1 part acid); weighing balances; a piece of wire.

A. Action of acid on bone.

Compare the two ribs as to form and size; place one of them in a bottle of diluted muriatic acid. Allow the bone to remain in the acid for a few days and then compare the two ribs again.

* This exercise may be performed by the pupil at home.

2

B.

1. Has the acid changed the form of the bone?
2. Has it changed the size of the bone?
3. What change do you observe to have taken place?
4. Pour some of the liquid in which the bone has been soaking into an evaporating-dish and heat over an alcohol-lamp or over a gas-flame until the liquid has disappeared. What kind of substance is left in the dish? (This substance is a kind of mineral matter formed from the mineral matter of the bone by the action of the acid.)
5. What properties of bone are due to the presence of mineral matter?

B. Effect of burning bone.

Weigh half of the long bone used in 1. Tie a piece of wire about it and place it in a hot coal fire. Allow it to remain for a half-hour and then remove it carefully by means of the wire.

1. Write in your note book a brief account of *all* the changes which you observed while the bone was in the fire.
2. Has the bone been changed in form or size?
3. What change can you see in the bone?
4. What part of the bone has been most affected by the fire?
5. Try to break the bone; what is the use in bone of the substance which has been lost?
6. Weigh the bone and determine what per cent of the original bone remains as ash (mineral matter) and what per cent has disappeared (animal matter).

C. Effect of boiling bones in water.

Place the other half of the soup-bone in a pint of water and allow it to simmer on the back of the stove for 4 to 6 hours. Strain the liquid through a cloth and allow it to cool.

1. Describe the substance which is obtained.
2. Set aside a small portion of this "soup-stock" to test it later for nutrients.

3. Classification of Bones.

From the articulated skeleton make lists of

1. Long bones (distinguished by shaft and articular extremities or heads).
2. Short bones.
3. Tabular or flat bones.
4. Irregular bones.

4. Study of the Muscles.*

Definitions.

1. The part of the muscle which contracts is the *belly;* the bands or cords at the ends are the *tendons.*
2. The end of the muscle which moves least is called the *origin;* the part which moves most, the *insertion.*
3. Muscles which bend or flex the limb are called *flexors;* muscles which straighten or extend the limb, *extensors.*

A. The biceps muscle.

1. Clasp the front of the right upper arm with the left hand; draw up or flex the right forearm as far as possible. What changes do you notice in the belly of the muscle?
2. Span the biceps muscle of the right arm by placing the tips of the fingers of the left hand at the angle of the elbow in front and the thumb as far up on the arm as possible; again flex the right forearm. What changes in the muscle other than those already enumerated do you notice?
3. Roll up the sleeve as far as possible. With a tape-measure get the circumference of the upper arm when it hangs free, and again when the forearm is strongly flexed. Write down your results.
4. Place the fingers of the left hand at the angle in front of the elbow of the right arm; flex and extend the right forearm several times. Note the cord or tendon at the lower end of the biceps muscle. To which of the bones of the forearm does it seem to be attached?
5. Determine if possible by moving the forearm the bones to which the upper end of the biceps is attached.
6. Find on the articulated skeleton in class the rough prominences to which the tendons of this muscle are attached.

B. The triceps muscle.

1. Clasp the back of the right upper arm with the

left hand; forcibly straighten or extend the right forearm. Locate the belly of the triceps with reference to the belly of the biceps. Locate both muscles with reference to the humerus.

2. By flexing and extending the forearm determine the position of the lower tendon of the triceps. To which bone of the forearm is it attached?

C. The flexor muscles of the fingers and of the thumb.

1. Clasp the front side of the right forearm near the elbow; clench the hand quickly and forcibly. Locate the belly of this flexor muscle with reference to the bones of the forearm.
2. Press the forefinger and thumb strongly together. What change is noticed in the thick mass of muscle at the base of the thumb? Along what bone does the flexor muscle of the thumb lie?
3. Measure the circumference of the forearm when the hand is open, and again when it is tightly closed. Record your results. Compare with figures for biceps.
4. Flex the fingers and note the movements of the tendons in the wrist. Along what bones do these tendons pass?
5. What would be the form of the hand if the flexor muscles of the fingers were located in a position corresponding to the flexor muscle of the thumb? What is gained by placing these muscles in the forearm?

D. The extensor muscles of the fingers.

1. Straighten back the fingers as far as possible and by feeling of the back of the forearm locate the belly of the extensor muscles of the fingers.
2. Move the middle finger alone. Describe the movements of the tendons on the back of the hand.
3. Flex the middle finger of each hand until it touches the palm of the hand; place the two hands together (palms facing) so that the tips of the forefingers, fourth fingers, and little fingers touch, pressing the backs of the middle fingers closely together. Try to separate each of the pairs of fingers, still keeping the middle fingers pressed together. Explain result.

E. The muscles which move the ankle.

1. Stand on tiptoe and locate in the calf of the leg the belly of the extensor muscles of the foot which cause this movement. To which bone is the lower tendon of this muscle (tendon of Achilles) attached?
2. Determine the position of the flexor muscle of the foot by flexing the ankle as far as possible. Which is the larger, the flexor or the extensor? Why?

F. The jaw-muscles.

Alternately close the jaws tightly together and open them. Find the muscles which cause these movements. Watch in the glass and describe the movements of these muscles.

Fill out in your note-book a table like the following:

Name of muscle.	Origin attached to what bone or bones.	Belly opposite what bone or bones.	Insertion attached to what bone or bones.
Biceps....................			
Triceps....................			
Flexor muscles of fingers...			
Extensor muscles of fingers.			
Flexor muscles of foot......			
Extensor muscles of foot....			

5. Study of Lean Meat (Muscle).

Materials: Slices of meat from the shank of beef about an inch thick. Cut the slices into blocks about a half-inch square. The structure is more clearly seen if the meat is allowed to dry in the air for a few hours. Dissecting needles, slide and cover glass, compound microscope ⅛″ objective.

A. Gross structure of muscle.

1. What is the shape of the small bundles (fasciculi) of which the muscle is composed? Do all of the bundles appear of the same shape when seen in cross-section?
2. What are the characteristics of the material surrounding the bundles (perimysium)?
3. Can you distinguish any fat in the piece of meat which you are studying? If so, where is it situated?
4. Is tendon present?
5. Make a drawing of the piece of muscle showing cross and longitudinal sections (× 5). Label bundles, perimysium, and fat and tendons if present.

B. Microscopic structure of muscle.

Separate with dissecting needles a small portion of the muscle; cover it with water and tear it apart with the needles until you have the smallest portion of the bundle which you can get. Place this bit of muscle on a glass slide, add a drop of water, and tease it out with needles; cover with glass and examine under the high power of the compound microscope.

1. Of what is the piece of muscle found to consist?
2. Why is this kind of muscle called striped muscle?
3. Draw a muscle-bundle as seen under the microscope. Label fibres, cross-stripes.

6. Structure of a Joint.

Materials: Fresh leg-joint of lamb or veal; scalpel.

A. Movement at the joint.

1. Holding one of the bones in a fixed position, in how many directions can the other bone be moved?
2. Why is the joint immovable in other directions?

B. Muscles and tendons.

1. Dissect away the muscle with the scalpel; by what are the muscles attached to the bones?
2. Try to stretch or break these cords (tendons); what properties of tendons does this demonstrate?

3. What is the advantage of the absence of muscle-tissue over joints?

C. Ligaments.

1. What kind of tissue holds the bones together after the muscle is removed?
2. How is this tissue attached to bone so as to allow movement at the joint?

D. Joint-cavity.

1. Cut through the ligaments with a scalpel so as to open the joint-cavity; what is the appearance of the liquid within (synovial fluid)?
2. Suggest the use of the synovial fluid.

E. Cartilage.

1. Cut thin slices of cartilage from the ends of the bones; what are the characteristics of cartilage?
2. Why is cartilage placed at the ends of bones where motion occurs?

F. Bones.

1. Describe the way the bones fit together at the joint.
2. Is twisting motion possible at this joint?

G. Periosteum.

Stick the point of the scalpel into the surface of the bone where all the muscle has been removed. Peel off some of the thin membrane (periosteum).

1. What are the characteristics of periosteum?
2. Where do you find periosteum on long bones?

H. Make a list of all the structures found in the joint, giving the use of each.

7. Study of the Joints in the Body.

A. Ball-and-socket joints.

1. Note on the articulated skeleton what bones form the joint at the shoulder.
2. Point out the bones forming the hip-joint.
3. State the points of resemblance between these two joints.
4. Mention all the differences in the structure of these two joints which you can see.
5. Move your right arm and right leg at the same time from a vertical position in an arc toward the right; state the greatest range of motion possible at the shoulder-joint and at the hip-joint.
6. In the same way move the arm and leg in an arc forward as far as possible; backward as far as possible. Compare the range of motion at each joint.
7. What other kinds of movements are possible at these joints?
8. Press the thumb on the hip-bone during these movements, then on the edge of the shoulder-blade. Is either of the two girdles movable?

B. Hinge-joints.

1. Determine from the articulated skeleton the bones which form the hinge-joint at the elbow.
2. What bones form the joint at the knee?
3. What projection at the elbow occupies a

position corresponding to the knee-cap or patella?

4. Move the right forearm and the right leg at the same time; state in which direction (i.e., anteriorly or posteriorly) each is bent.
5. Is lateral motion possible at either joint?
6. Make a list of all the other hinge-joints in the body, naming the bones which form the joint in each case.

C. Pivot-joints.

1. Place the right forearm on the table with the palm of the hand upward. Without lifting the elbow from the table turn the hand until the palm of the hand rests on the table.
   a. Which of the bones of the forearm has crossed the other?
   b. Note on the articulated skeleton what two bones form this pivot-joint at the elbow.
2. Study the two top vertebræ of the spinal column; move the vertebræ on each other to show how a person may turn his head from side to side.

D. Gliding joints.

1. Count on the articulated skeleton the bones forming the wrist.
2. How many bones form the ankle?
3. Which bones are the larger, those of wrist or ankle?
4. Move your right wrist and right ankle in the same direction at the same time. At which

joint is the greater range of movement possible?

5. Move your lower jaw in as many directions as you can.
   a. At what joint does this movement take place?
   b. To which class does this joint belong?
6. Study the joints between the vertebræ; move the vertebræ on each other to show how one may bend the back or twist the spinal column.

8. Experiments with Joint Apparatus.

Note.—This apparatus was devised by Dr. G. W. Fitz of Harvard University. The experiment is adapted from "Outline of Requirements" for Harvard.

A. Action of biceps muscle.

1. Fasten at hole No. 3 the lower end of the chain attached to balance No. 1, and suspend this balance from the wire which slides on the upright rod. This balance represents amount of force exerted by the biceps muscle.
2. Fasten at hole No. 5 balance No. 3, so that it hangs below the square tube. This balance shows the weight in palm of the hand lifted by the biceps muscle.
3. Balance No. 2, attached to upright rod and sleeve, shows amount of pressure in joint.
4. Pull up the sliding wire on the upright rod.

5. Pull on balance No. 3 until the square tube is at right angles to the upright rod, i.e., the forearm is horizontal.
6. Read the pressure in pounds and fractions of pounds on each balance, and record them in the table given below.
7. Fix the sliding wire in other positions on the upright rod, and get other sets of figures.
8. Record all your results in a table as follows:

Balance No. 1.	Balance No. 2.	Balance No. 3.

9. What relation do you find to exist between the force exerted by the biceps (balance No. 1) and the sum of the forces exerted at the joint (balance No. 2) and on the palm of the hand (balance No. 3)?
10. Determine from a study of your results above how much force must be exerted by the biceps muscle in order to lift 10 pounds in the palm of the hand. How much force must be exerted to lift 25 pounds?

B. Action of triceps muscle.

1. Fasten at hole No. 2 the lower end of the chain attached to balance No. 1, and suspend this balance from the wire which slides on the upright rod. This balance represents the amount of force exerted by the triceps muscle.
2. Fasten at hole No. 5 balance No. 3, so that it

may be used to pull up the square tube. This balance shows the weight in palm of hand moved by triceps muscle.

3. Balance No. 2, attached to upright rod and sleeve, shows amount of pressure in joint.
4. Pull up the sliding wire on the upright rod.
5. Pull up on balance No. 3 until the square rod is at right angles with the upright rod, i.e., the forearm is horizontal.
6. Fill in several sets of figures in the following table by experimenting in a manner similar to that suggested in A, 6, 7 above :

Balance No. 1.	Balance No. 2.	Balance No. 3.

7. What relation do you find to exist between the force at the joint (balance No. 2), and the sum of the forces exerted by the triceps (balance No. 1) and at the palm of the hand (balance No. 3)?

C. Action of the calf-muscles.

1. Fasten at hole No. 1 the lower end of the chain attached to balance No. 1, and suspend this balance from the wire which slides on the upright rod. This balance shows the amount of force exerted by the muscles in the calf of the leg which pull on the tendon of Achilles.
2. Fasten at hole No. 4, by means of the pin, balance No. 3, so that it may be used to pull

up the square tube. This balance shows the pressure exerted on the floor by the ball of the foot.

3. Balance No. 2, attached to the upright rod and sleeve, shows amount of pressure on ankle-joint exerted by weight of body.
4. Experiment with this arrangement of the lever apparatus until you obtain several sets of figures. (See directions A, 4, 5, 6, 7 above.)
5. Record all your results in a table as follows:

Balance No. 1.	Balance No. 2.	Balance No. 3.

6. From a study of your results above compute the following:

When a person weighing 150 pounds stands on one foot with the weight on the ball of the foot—

a. What pressure is exerted on the floor?

b. What force is pulling on the tendon of Achilles in order to produce the above position?

c. What is the pressure on the ankle-joint?

Answer the same questions when the person weighs 100 pounds.

9. Acid and Alkaline Reactions.

Materials: Diluted hydrochloric acid, dilute caustic soda solution; red and blue litmus paper; evaporating-dish, alcohol-lamp.

A. Tests for acids and alkalis.
   1. Place a drop of very dilute hydrochloric acid on blue litmus paper. Result?
   2. Place a drop of very dilute caustic soda solution on red litmus paper. Result?
   3. Place a drop of the hydrochloric acid on the tongue. What is the taste?
   4. In the same way determine the taste of the soda solution.

B. Neutralization.
   1. Pour a small amount of the hydrochloric acid into an evaporating-dish; add caustic soda, drop by drop, until pieces of red and blue litmus paper remain unchanged when dipped into the liquid. This process is called neutralization.
   2. Evaporate the liquid in the dish to dryness over an alcohol- or gas-flame.
      a. What is the appearance of the substance which is left?
      b. What is its taste?

C. Definitions. From the above experiments—
   1. Give some characteristics of an acid.
   2. Give some characteristics of an alkali.
   3. Define neutralization.

D. Applications.
   1. Test with litmus paper the following sub-

stances dissolved in water: soap, lemon-juice, ammonia, cream of tartar, saliva, baking-soda, apple-juice, sugar, white of egg.

2. Arrange all the substances you have tested in a table like the following:

Acid.	Alkali.	Neutral.

10. To Determine the Amount of Water in Foods.

Materials: Piece of lean beef-steak; two potatoes; weighing balances.

A. Percentage of water in beef-steak.

1. Weigh the piece of meat and put it aside in a warm dry place; weigh the next day. Continue the weighings each day until the figure remains constant. (The loss is mostly water.)
2. Record your results in tabular form as follows:

	Wt. of steak.	Loss of original wt.	Per cent. of loss.
First day..........			
Second day.........			
Third day..........			
etc.			

B. Percentage of water in potatoes.

1. Remove a thin layer of peel from one of the potatoes; weigh each of them and lay aside

in a warm dry place. Weigh each day, and record results for each potato in tabular form as above.

2. What is one use of the peel of potato?

11. To Test Foods for Starch.*

Materials: Corn-starch, grape-sugar, white of egg, mutton tallow, water; iodine solution; test-tubes, glass jar, alcohol-lamp.

A. Method of applying iodine test.

Put a small amount of corn-starch in a test-tube, add water and shake the mixture.

1. Does the starch dissolve?
2. Boil the mixture.
   a. What change do you notice?
   b. Has the starch dissolved? (Place some sugar and water in another test-tube, boil, and compare with the boiled starch.)
3. Pour a little of the starch paste into a test-tube, add a drop of iodine, and record result.
4. Add a few drops of the starch mixture to a large glassful of water; stir in a few drops of iodine. What is the result?
5. Pour a small amount of iodine into a test-tube of water. What do you observe?
6. Put a small amount of grape-sugar into a test-tube; into a second test-tube some white of egg mixed with water; and into a third tube put some mutton tallow (fat). Add a little iodine to each.

a. Do you notice any change in the color of any of the substances?

b. Do any of the colors resemble at all the change of color resulting from the addition of iodine to starch?

7. From the preceding experiments state how you may determine whether a substance contains much starch, little starch, or no starch.

B. Application of iodine test to various foods.

1. Test as many foods as you can by adding hot water to each on a porcelain dish and then applying iodine (e.g., oatmeal, flour, meat, egg, milk, parsnip, potato, onions, apples (both green and ripe), beans, rice, pepper).

2. Tabulate your results in columns under the following heads:

Much starch.	Little starch.	No starch.

12. To Test Foods for Grape-sugar.*

Materials: Grape-sugar, corn-starch, white of egg, mutton tallow, raisins, onions, grapes, granulated sugar, and other foods; Fehling's solution; test-tubes, alcohol-lamp.

A. Method of applying Fehling's test.

1. Dissolve a small amount of grape-sugar (glucose) in water in a test-tube.

a. What is the taste of the solution?

b. Add some Fehling's solution and boil. What changes do you notice?

2. Into the first of three test-tubes put some white of egg mixed with water; into a second tube some corn-starch; and into a third tube some mutton tallow (fat). Add Fehling's solution to each and boil.
   a. Does any change take place in the color of the Fehling's solution?
   b. Do any of the colors resemble at all the color of the Fehling's solution when it was boiled with grape-sugar?
3. How can you determine whether or not grape-sugar is present in a given food?

B. Application of Fehling's solution test to various foods.

1. Test as many different kinds of foods as you can, first treating them with water, boiling in a test-tube and then boiling with Fehling's solution (e.g., onions, grapes both ripe and unripe, pears, granulated sugar, honey, molasses, meat, egg).
2. Tabulate your results in columns under the following heads:

Grape-sugar present.	Grape-sugar absent.

13. To Test Foods for Nitrogenous Substances.

Materials : White of egg, corn-starch, grape-sugar, mutton tallow, piece of meat, milk, peas ; concentrated nitric acid and ammonia ; test-tubes, beaker-glass, thermometer, alcohol-lamp.

A. Effect of heat.

1. Pour a small amount of the white of an egg into a test-tube. (White of egg is composed of nitrogenous substances.) Place a chemical thermometer in the test-tube, and hold the tube in a beaker-glass of cool water. Gradually heat the water, stirring continually with the test-tube.
    a. What change takes place in the egg albumen?
    b. At what temperature does this change occur?
2. In the same way try the effect of heat on milk (heating several times); on meat. Record results.

B. Smell when burning.

1. Place a small piece of lean meat on the top of a coal fire and allow it to burn. Have you ever noticed this smell before? If so, what caused it?
2. In the same way test milk, peas, or beans. Result?

C. Effect of nitric acid and ammonia.

1. Pour a little concentrated nitric acid on a piece of hard-boiled egg in a test-tube.
    a. What do you observe?

b. Wash off the egg with water, add a little concentrated ammonia, and note result.

2. Put into a test-tube some starch paste made as in 11 above; into a second tube some grape-sugar; and into a third test-tube some mutton tallow (fat). Add a little concentrated nitric acid to each of the three.
   a. Do you observe any change in the color of either of these nutrients?
   b. Pour off the acid and add a little concentrated ammonia. Is any effect noticeable?
3. Test with a drop of nitric acid the skin on the tip of one of your fingers.
   a. What is the result?
   b. Of what material is the human body partly composed?
4. Apply the nitric acid and ammonia test to as many foods as you can (e.g., gelatin, peas, white meats, onions, fruits).
5. Tabulate your results in columns under the following heads:

Nitrogenous substances present.	Nitrogenous substances absent.

D. From the above experiments state briefly three ways of testing foods for nitrogenous substances.

14. To Test Foods for Fats and Oils.

Materials : Ground flaxseed, corn-meal, milk, egg ; ether or benzine ; beaker-glass.

Caution ! Never handle benzine or ether near a flame or a hot stove, since the vapor of these substances is very inflammable.

A. Method of extracting oils.

To two or three teaspoonfuls of the ground flaxseed add an equal volume of ether or benzine ; stir the mixture and let it stand for ten or fifteen minutes. Filter and place the liquid aside in a good draught of air until the odor of ether or benzine has disappeared.

1. What kind of substance have you obtained ?
2. What is its smell ?
3. Why is benzine used to remove grease-spots from clothing ?

B. In the same way extract the fats from milk ; from egg.

C. Rub a little of the flaxseed on paper. What effect does it have on the paper ? (This is a simple way of proving the presence of fats.)

15. To Test Foods for Mineral Substances.*

Materials ; Piece of meat, oatmeal, egg, milk ; spoon or piece of metal.

A. Method of testing for mineral matter.

Place a piece of dried meat on a spoon or on a shovel, and let it burn on a hot coal fire or over a gas-flame until no other change can be brought about by heat.

1. What is the appearance of the substance which is left behind? (The ash is the mineral substance.)
2. What is the effect of heat on this substance?

B. In the same way test oatmeal, egg, and milk. What do you learn in regard to the presence of mineral substances in these foods?

16. The Analysis of Flour.*

Materials: Flour, water; concentrated nitric acid and ammonia, iodine, Fehling's solution; cotton cloth, test-tubes, glass dish, piece of metal.

Moisten some flour with water until it forms a tough, tenacious dough; tie it in a piece of cotton cloth, and knead it in a vessel containing water. Set aside the dish with the water.

A. Gluten.
   1. What are some of the characteristics of the substance (principally gluten) within the cloth? Draw it out into threads.
   2. Test it with nitric acid and ammonia. What kind of nutrient is gluten?

B. Carbohydrates.
   1. Test with iodine a small amount of the sediment in the water which you used at the beginning of the experiment. What part of the flour was washed through the cloth?
   2. Test with nitric acid and ammonia another portion. Are nitrogenous substances present?

3. Test a small portion of the sticky mass in the cloth with iodine. What is the result, and what is your conclusion?
4. Place a little flour in a test-tube, add water and boil; add Fehling's solution and boil again. Is grape-sugar present in flour?

C. Mineral matter.

Place a small amount of dry flour on a piece of tin or other metal and cause it to burn over a flame.

1. What changes take place?
2. What is left after the burning?

D. Summary.

1. What nutrients are present in flour?
2. State how each of these nutrients may be separated from the rest.

17. The Study of Milk.*

Materials: Pint of fresh, rich milk; nitric acid and ammonia, Fehling's solution, iodine, caustic soda, osmic acid, vinegar; test-tubes, lactometer, cloth, piece of metal, alcohol-lamp.

A. Fats.

Put the milk into a clean glass dish, and allow it to stand over night.

1. What layers can be distinguished?
2. Remove by means of a spoon the top layer into a bottle or cup (No. 1).
3. Place a drop of it on unglazed paper. Let the paper dry for some time. What kind of nutrient is shown to be present in milk?

B. Nitrogenous substances.

1. Boil the rest of the milk; what change is noticed? What kind of nutrient is affected in this way by heat?
2. Remove the scum from the milk and place it in a second cup (No. 2). Test a little of it with nitric acid and ammonia. Result?
3. Add vinegar to the rest of the milk and strain through a cloth. What kind of substance is left in the cloth? Test it with nitric acid and ammonia. Result? Place this substance in cup No. 2.

C. Carbohydrates.

1. Test a small amount of fresh milk with Fehling's solution. Result? (Milk-sugar or lactose sometimes gives the test with Fehling's solution like grape-sugar.)
2. Test milk with iodine. Is starch present?

D. Specific gravity of milk. (In class.)

1. Pour some good rich milk into a tall glass jar. Test it with a lactometer and record specific gravity.
2. Set the milk aside to allow the cream to rise. Remove the cream and test the skim-milk with the lactometer.
   a. What change in specific gravity do you note?
   b. Explain this change.
3. Determine the specific gravity of a second portion of milk. Dilute the milk with water and again find specific gravity. (Fresh unskimmed milk usually has a specific gravity

of 1028 to 1034.) How can adulteration of milk be detected?

E. Microscopic examination of milk. (In class.)

1. Place a drop of milk on a clean glass slide, and cover with a cover-glass. Examine under the compound microscope.
   a. What is the appearance of the oil-globules?
   b. Are they all of the same size? (The fat in milk is said to be in a state of emulsion.)
2. Place a drop of dilute caustic soda at the edge of the cover-glass. What is the effect of the soda on the oil-globules?
3. Prepare a second drop of milk for examination as directed above (1). Place a drop of osmic acid solution at the edge of the cover-glass. What is the effect of the osmic acid on the oil-globules?

F. Reaction of milk when tested with litmus.

1. Test some fresh milk with red and blue litmus paper. Is it acid, alkaline, or neutral?
2. Set the milk aside in a warm place and allow it to sour. Again test it with the red and blue litmus paper. What is its reaction now? (The souring of milk is caused by the action of certain micro-organisms called bacteria. See study of bacteria, 44.)

18. The Study of the Mouth.*

Take a position with your back toward a strong light and study your mouth-cavity by means of a hand-mirror.

A. Walls of the mouth-cavity.

1. Press the forefinger against the upper, lower, and side walls of the mouth; in which of these regions are the walls rigid (bone)? in which regions are they yielding (muscle)?
2. What differences do you note between the outer and inner coverings of the cheek? What are the characteristics of mucous membrane (inner covering)?
3. Pull aside with the forefinger one corner of the mouth. Notice the small elevation on the inside of the cheek. Opposite what tooth does it lie? (The duct from one of the salivary glands opens on this elevation.)
4. Press the tongue down with the forefinger. Describe, with figure, the opening into the throat or pharynx.
5. If possible, locate and describe the tonsils.

B. The teeth.

1. Close the jaws and open the lips; do the front teeth of the upper jaw cover the ends of the lower teeth or *vice versa?*
2. Are the front teeth of the upper jaw larger or smaller than those of the lower jaw?
3. Count your teeth and record result in a table like the following:

	Right half of upper jaw.	Left half of upper jaw.	Right half of lower jaw.	Left half of lower jaw.
Incisors.....				
Canines.....				
Bicuspids....				
Molar.......				

4. Place a piece of string between the teeth and describe motion of jaws in biting it off. Describe the movements of the jaws in chewing.

C. The tongue.

1. What is the shape of the tongue?
2. Where is the tongue attached?
3. What parts of the walls of the mouth-cavity can be touched by the tip of the tongue?
4. What differences do you note between the upper and lower surfaces of the tongue?

D. The use of the lips and tongue in speaking.

1. Pronounce the vowels of the alphabet:
   a. Are the lips closed or open?
   b. Does the tip of the tongue touch the teeth?
   c. Does the tip of the tongue touch the palate?
   d. How is the shape of the mouth-cavity altered to pronounce these different letters?
2. What consonants necessitate the closing of the lips? (These consonants are called labials.)
3. What consonants require the tongue to touch the teeth or the palate? (These are called the lingual consonants.)

19. To Prepare Digestive Juices.†

Materials: Cardiac end of pig's stomach ; pancreas of pig ; gall of ox ; strong glycerin, .2% solution of hydrochloric acid, 1.5% solution of sodium carbonate ; solid pepsin, pancreatin, and ox-gall.

A. Preparation of pepsin solution.

Procure the stomach of a pig, wash it out with a gentle stream of water. Tear off the mucous membrane from the cardiac (œsophageal) end of the stomach. Dry the membrane between folds of blotting-paper, and mince it finely. Place in a bottle and add 5 times its bulk of strong glycerin. Set aside for several days, stirring occasionally. Filter through muslin. (The glycerin dissolves the pepsin.) The glycerin extract may be kept almost indefinitely.

When required for use in digesting nitrogenous substances, add 10 times its volume of .2% hydrochloric acid, and filter.

Instead of preparing the glycerin extract an artificial gastric juice may be made by dissolving solid pepsin in water and adding the hydrochloric acid.

B. Preparation of pancreatin solution.

Leave the pancreas of a pig moistened with water for a day ; then mince it well and add 10 times its volume of strong glycerin. Set the mixture aside for several days, stirring occasionally. Filter through muslin. (The glycerin dissolves out the pancreatin.)

The glycerin extract acts on starch and nitrogenous substances. When required to digest fats add 10 volumes of 1.5% solution of sodium carbonate, shake and filter.

An artificial pancreatic juice may be made by dissolving solid pancreatin in water and adding the sodium carbonate solution.

C. Preparation of bile.

Procure the fresh gall-bladder of an ox; wash it, make a small opening with a knife, and collect the bile in a bottle. (The bile of herbivorous animals is green in color; human bile when fresh is a golden-brown liquid.)

A solution of solid ox-gall in water may be used instead of the contents of the gall-bladder, if the latter cannot be easily obtained.

20. The Digestion of Starch.

Materials: Corn-starch, pancreatin solution, saliva; test-tubes; alcohol-lamp.

A. By saliva.

Put a small amount of corn-starch in a test-tube, add water and boil; dilute the paste until a smooth, thin mixture is formed.

1. Pour into a test-tube a small amount of this starch mixture, and test with Fehling's solution. What is the result and what is your conclusion?
2. Allow some saliva to flow from the mouth into a clean test-tube;* test it with Fehling's solution. What is your inference?

* Saliva sufficient for the class may be obtained by the teacher before the exercise.

3. Pour some saliva into the starch paste made at the beginning of the experiment, shake the mixture and warm gently for a moment or two. Test with Fehling's solution. Result?
4. What is the effect of saliva on boiled starch?
5. Name several foods already studied which might be partially digested by saliva.
6. Hold a small amount of the boiled dilute starch paste in the mouth. What is the taste at first? Do you notice any change; if so, what change?

B. By pancreatic juice.

1. Dissolve a little pancreatin in water. Test a small portion of it with Fehling's solution. What is your conclusion?
2. Add some pancreatin solution to some of the starch paste; warm and test with Fehling's solution. Result?

C. What digestive juices of the human body act upon starch?

21. The Digestion of Mineral Substances.

Materials: Table-salt, phosphate of lime, diluted hydrochloric acid; evaporating-dish, alcohol-lamp.

A. Soluble salts.

Put some table-salt into a test-tube, add water, and shake well.

1. Does the salt dissolve? How do you know?
2. In what part of the alimentary canal may salt become liquefied, and how?

3. What is meant by a soluble salt or soluble mineral substance?

B. Insoluble salts.

Put some phosphate of lime (one of the constituents of milk) into a test-tube, add water, and shake well.

1. Does the substance dissolve? How do you know?
2. Add a little diluted hydrochloric acid and shake. What change do you observe?
3. Evaporate to dryness in an evaporating-dish some of the liquid obtained in 2.
   a. What is the appearance of the substance which is left?
   b. Will it dissolve in water?
   c. Into what kind of a salt has hydrochloric acid changed the insoluble salt?

22. The Digestion of Nitrogenous Substances.

Materials: **Hard-boiled egg; pepsin and pancreatin solutions, hydrochloric acid, bicarbonate of soda; test-tubes.**

A. Test No. 1

Thoroughly mince a piece of hard-boiled egg, and place a portion of it in a test-tube; half-fill the tube with water; add some pepsin. Label the tube "No. 1, Minced egg + pepsin."

B. Test No. 2.

Place in another test-tube the same quantity of minced egg, water, and pepsin as in tube No. 1; add a little dilute hydrochloric acid. Label "No. 2, Minced egg + pepsin + hydrochloric acid."

C. Test No. 3.

Put a lump of the hard-boiled egg in a test-tube; add water, pepsin, and hydrochloric acid as in tube No. 2. Label "No. 3, Lump of egg + pepsin + hydrochloric acid."

D. Test No. 4.

Into another test-tube put some of the minced egg; half-fill the tube with water and add pancreatin; pour in a few drops of dilute hydrochloric acid. Label "No. 4, Minced egg + pancreatin + hydrochloric acid."

E. Test No. 5.

In a fifth test-tube mix the same quantity of minced egg, water, and pancreatin as was used in No. 4; add to the mixture a little baking-soda. Label "No. 5, Minced egg + pancreatin + baking-soda."

Shake all five mixtures well and set them aside in a warm place. Examine them at the end of the first few hours, at the end of 24 hours, etc.

F. Results.

1. Compare tubes No. 1 and No. 2.
   a. In which tube has the egg been liquefied or digested?
   b. Is the acid necessary for gastric digestion?
2. Compare tubes No. 2 and No. 3.
   a. In which tube is digestion more complete?
   b. What do you learn in regard to the effect of thorough mastication of food?

3. Compare tubes No. 4 and No. 5.
   a. In which tube has digestion taken place?
   b. Does pancreatin perform its digestive action in an acid or in an alkaline medium?

23. The Digestion of Fats.

Materials: Butter, olive-oil, lard, white of egg; sodium carbonate, caustic soda, hydrochloric acid; bile, pancreatin; test-tubes, thermometer, beaker-glass of water, alcohol-lamp, apparatus-stand; compound microscope, slide, cover-glass.

A. Effect of heat on fats.
   1. Put a small piece of butter in a test tube; hold the test-tube and the thermometer in a beaker-glass of water, and heat the water.
   2. At what temperature does the butter melt?
   3. Does this change take place below the temperature of the body (98.5° Fahrenheit) i.e., will butter melt in the mouth?

B. Emulsion of fats.
   1. In a test-tube shake up a few drops of olive-oil with some caustic soda solution.
      a. What change takes place in the appearance of the mixture after shaking? (This mixture is called an emulsion.)
      b. Put a drop of the mixture on a glass slide, cover with a cover-glass, and examine with a compound microscope.
         (1) What is the appearance of the oil droplets?

(2) Compare this appearance with that seen in milk.

2. In a test-tube shake some olive-oil with a mixture of white of egg (albumen) and water.
   a. What is the appearance of the mixture?
   b. Examine a drop under the compound microscope as directed above.
3. Shake up a few drops of the olive-oil with water in a third test-tube.
   a. Compare the mixture of oil and water with the mixtures formed in 1 and 2 above.
   b. What differences do you notice in the tubes?
4. Summary.
   a. Define an emulsion.
   b. State two ways in which an emulsion may be made.

C. Saponification of fats.

1. Put a little lard or olive oil in a test-tube, add caustic soda, and boil.
   a. What is the appearance of the mixture?
   b. Examine a drop under the compound microscope as directed above. Do you see any difference between this mixture and that formed in B 1 above?
   c. Taste of the mixture. What kind of substance has been formed?
2. What is meant by saponification?

D. Effect of acids and alkalis on fats.

1. Pour a little melted butter into each of two test-tubes. Add to test-tube No. 1 some diluted hydrochloric acid ; to test-tube No. 2 some sodium carbonate solution. Shake both tubes well, and allow them to stand for a few moments.
2. Does the butter remain mixed better with an acid or with an alkali?

E. The digestive action of bile.

1. Test with litmus paper the bile solution. Is it acid, alkaline, or neutral?
2. Pour a little melted butter into a test-tube; add some of the bile solution. Does the mixture resemble that formed in B 1 or B 3 above?
3. Examine a drop of the mixture under the compound microscope. Does this observation agree with that made in 2 just above?
4. Pour a little thin starch paste into a test-tube; add some bile, and after a time test the mixture with Fehling's solution. Does the bile act upon starch?
5. Place in another test-tube a little minced white of egg; add bile and set aside for a day or two. Does the egg dissolve?
6. State what kinds of food-stuffs are acted upon by bile, and what kinds of food-stuffs are not acted upon.

F. The digestive action of pancreatic juice.

1. Prepare some artificial pancreatic juice as directed in 19 B, adding the sodium carbonate solution to make it alkaline.

2. Shake up a little melted butter with some of this pancreatic juice. What kind of a mixture is formed? Examine under the compound microscope.
3. What kind of food-stuffs are digested by the action of pancreatic juice (compare previous experiments), and what kind of food-stuffs are not acted upon?

24. The Principles of Osmosis. †

Materials: Tubes of animal intestine, thistle-tube, beaker-glass, grape-sugar, starch, white of egg, butter, salt, Fehling's solution, iodine, nitric acid and ammonia.

Procure the intestines of a sheep. Clean and inflate them; tie at intervals of 8 inches, and allow this animal membrane to dry. Cut the successive portions of the intestines in such a way as to form small tubes closed at one end.

A. Experiments to determine what nutrients will pass through an animal membrane.

Suspend by a piece of wire in a beaker-glass of water one of the test-tubes made by cutting up the dried intestines. Carefully pour into the tube a solution of grape-sugar. Allow it to stand for an hour.

1. Test the water on the outside of the tube with Fehling's solution. What is the result?
2. Will grape-sugar pass through an animal membrane?
3. Using other tubes of animal membrane, determine whether starch, white of egg (al-

bumen), butter, or salt solution will pass out into the water outside the tube. (See Experiments 10–14 above.)

4. Classify all the substances you have tested in a table like the following:

CRYSTALLOIDS. (Substances which will readily pass through an animal membrane.)	COLLOIDS. (Substances which will not readily pass through an animal membrane.)

B. Experiments to illustrate osmosis.

Slit open one of the tubes made from the sheep's intestine and cover the larger end of a thistle-tube with a piece of this membrane, tying it tightly. Pour into the smaller end of the thistle-tube a rather thick solution of grape-sugar, half-filling the tube. Stand the thistle-tube (membrane down) in a glass dish filled with water up to the level of the grape-sugar solution. Mark this point on the glass dish. Connect a long piece of glass tubing to the smaller end of the thistle-tube and support it in a vertical position. Examine the apparatus at the end of several hours.

1. Notice the level now reached by the liquid within the thistle-tube. What change has taken place since the experiment was begun?
2. Measure the difference between the level of the liquid within the thistle-tube and the level of the liquid in the glass dish.

3. Test the water on the outside of the thistle-tube (in the glass dish) with Fehling's solution. What is the result?
4. How do you account for this result?
5. Which of the two liquids (the water in the glass dish or the grape-sugar solution in the thistle-tube) was the denser at the beginning of the experiment?
6. Has more liquid passed into the thistle-tube or out from it? How do you know?
7. When two liquids of different density are separated by an animal membrane what change takes place?
8. Is the greater flow of liquid from the less dense to the more dense or *vice versa?*
9. Mark the level of the liquid in the thistle-tube at the end of each successive 24 hours. What inferences do you draw?

NOTE.—Parchment paper may be used instead of the dried sheep's intestine to cover the end of the thistle-tube. Or a membrane may be obtained which will answer the purpose by dissolving the mineral portion of an egg-shell, leaving the lining membranes intact; the membrane may then be tied to the end of the tube.

C. Application of the experiments.

1. In what respects does the experiment with the thistle-tube illustrate the process of absorption from the alimentary canal?
2. In what respects does the experiment fail to illustrate that process?

25. Digestion of Nutrients.*

Kind of nutrient.	Digested in	Digested by	Changed to	Absorbed in
Water.				
Soluble salts.				
Insoluble salts. . . .				
Starch.				
"				
Sugar.				
Fats.				
"				
Nitrogenous foods.				
" "				

26. Composition of the Blood.

Materials: Concentrated nitric acid and ammonia, iodine solution, Fehling's solution; test-tubes, alcohol-lamp; three bottles of blood material prepared as follows: Fill bottle No. 1 with blood of the ox, (at slaughter-house), set it aside at once where it will not be disturbed, and leave it for a day or two, labelled "Clotted Blood." Collect some blood in a pail and rapidly whip it with a brush-broom or some twigs for several minutes; fill bottle No. 2 with the red liquid remaining in the pail, labelling it "Defibrinated Blood." Collect the stringy substance clinging to the broom, wash it with water until it is white, and place it in bottle No. 3 in a 2% solution of formalin or in 80% alcohol; label it "Blood-fibrin."

A. Study of clotted blood.

1. What is the shape, size, and consistency of the blood-clot?
2. What is the color of the clot?
3. What is the color of the liquid serum?
4. Pour off the serum into another bottle of the same size; what proportion of blood appears to be serum?

5. What change in the clot do you notice after the removal of the serum?

B. Study of blood-serum.

1. Pour a small portion of the serum into a test-tube and heat gradually over an alcohol-lamp; what change takes place? What kind of food-stuff do you conclude to be present in the serum?
2. Test the serum with iodine; what is your inference?
3. Test another portion of the serum with Fehling's solution. Result?
4. Place a drop of the serum on a piece of paper; how is the paper affected? What other food-stuff do you therefore conclude to be present?
5. Heat a small amount of the serum in a spoon until it has burned; what kind of substance is left?
6. Name all the kinds of food-stuffs you have found present in blood-serum.

C. Study of blood-fibrin.

1. Remove a piece of fibrin from bottle No. 3; pull it apart. What are some of its characteristics?
2. Test the fibrin with nitric acid and ammonia; what is its composition?

D. Study of defibrinated blood.

1. What ingredient of the blood is wanting in bottle No. 2? (See directions above.)
2. What is the effect on coagulation of removing this substance from blood?

27. Change in the Blood after Mixing with Oxygen.†

Materials: Defibrinated blood used in **26**; glass bottle and stopper.

A. Pour a small quantity of defibrinated blood into a glass bottle. Describe its color.

B. Stopper the bottle tightly and shake it violently for a minute or two.
   1. What change has taken place in the appearance of the blood?
   2. What caused this change?

28. Microscopic Study of Corpuscles.†

Materials: Prepared slides of frog's blood and of human blood; compound microscope (500 diameters).

A. Corpuscles of frog's blood.
   1. How many distinct types of solid bodies (corpuscles) can you see in the frog's blood?
   2. Is there any variation in the form or size of different corpuscles of the same type?
   3. Draw two corpuscles (differing as much as possible) of each type, much enlarged, labelling nucleus and cell-body.

B. Corpuscles of human blood.
   1. What is the form of the corpuscles in human blood? (Examine several corpuscles before deciding.)
   2. In what respects do these corpuscles differ from those found in frog's blood?

29. Study of the Heart.

Materials: Sheep's heart dissected according to the directions given in Martin's "Briefer Course," pp. 211–215 (Edition 1895), pp. 363–369 (Edition 1898).

A. Using the descriptive terms anterior and posterior, dorsal and ventral, right and left (with reference to the animal), locate the following structures in the heart, giving, when possible, the number of each:

1. Auricles.
2. Ventricles.
3. Semilunar valves.
4. Tricuspid valve.
5. Mitral valve.
6. Papillary muscles.
7. Chordæ tendineæ.

B. Name the chamber of the heart with which each of the following blood-vessels is connected:

1. Aorta.
2. Pulmonary artery.
3. Pulmonary veins.
4. Venæ cavæ.

C. State all the differences which you note between—

1. Dorsal and ventral surfaces of the heart.
2. Anterior and posterior ends of the heart.
3. Auricles and ventricles.
4. Largest veins and largest arteries.
5. Mitral and tricuspid valves.
6. Mitral and tricuspid valves and semilunar valves.

D. Enumerate the differences between the right and left sides of the heart.

30. Circulation of the Blood in the Tail of the Tadpole.†

Cut a hole a half-inch square near the end of a piece of thin board three inches long and one inch wide; glue a thin cover-glass over the hole. Cover the rest of the piece of wood with absorbent cotton soaked in water. Lay a live tadpole on the cotton, placing the tip of the tail on the cover-glass. Lay a cover-glass on top of the tail, and fasten cheesecloth over the animal to keep it in place. Keep a plentiful supply of moisture about the animal, by allowing the end of the strip of cloth to dip into a dish of water. Examine the tip of the tail with a compound microscope magnifying about 75 diameters.

1. At the highest focus note the epithelial cells forming the outside layer of the body covering. What is their shape?
2. What is the shape of the dark pigment-cells seen just beneath the epithelial cells?
3. Focus still lower and study the flow of the blood in the small capillaries.
    - *a.* Is the current steady in all the blood-vessels which you see?
    - *b.* Do the red corpuscles alter in shape as they move along?
    - *c.* Can you distinguish any colorless corpuscles?
    - *d.* Draw a small area of the tail, representing the course of the capillaries. Indicate by arrows the course of the blood in each capillary.

NOTE.—If tadpoles cannot be obtained, the web of a frog's foot may be examined after confining the frog on a larger piece of board than that described above.

31. The Pulse in the Pupil's own Body.*

To take the pulse place the forefinger of the left hand on the radial artery of the right hand at the lower end of the radius bone on the palm side.

A. Variations in the pulse-beat.

1. Make out in your note-book a statement of your pulse-rate taken under the following conditions:
   - *a.* Before rising in the morning.
   - *b.* Just before eating breakfast.
   - *c.* Just after breakfast.
   - *d.* Just after some violent exercise.
2. What is your conclusion from these observations?

B. Find your pulse in the following places on your body, locating each with reference to the bones of the skeleton:

1. On the side of the head in front of the ear. Trace this artery as far as possible.
2. On the back of the head near the top of the neck.
3. On the side of the lower jaw.
4. In the hollow back of the knee-joint.
5. On the ankle.

32. Properties of Carbon.*

Materials: Match, meat, flour, egg; alcohol-lamp.

A. Strike a match and allow it to burn until the wood is charred. Extinguish the flame.
   1. What is the appearance of the substance (carbon) which is left?
   2. Hold it in the flame of an alcohol-lamp. What change takes place in the carbon?
   3. What kind of substance is left? Heat this as hot as you can. Describe any changes.
   4. What is one method of showing the probable presence of carbon in a substance?

B. Scorch some meat, some flour, and some egg.
   1. Do they contain any carbon? Why do you think so?
   2. How is the human body supplied with new portions of the element carbon?

33. Tests for Carbon Dioxide.

Materials: Splinter of wood; bottle and stopper; lime-water.

A. Insert one end of a splinter of wood in the cork; light the splinter, place it in the bottle and cork tightly.
   1. Record your observations.
   2. Insert a glowing stick; result? (The hot carbon has united with the oxygen of the air, forming carbon dioxide.)

B. Pour a small quantity of clear lime-water into the bottle in which the stick was burned, stopper the bottle and shake.

1. What change do you notice in the lime water?
2. State the method of testing for carbon dioxide.

34. Temperature of the Body.*

A. Place the bulb of a chemical thermometer beneath the tongue, closing the lips over it.

1. To what point does the mercury rise?
2. Is the temperature which you have determined the same as that found by the other pupils?
3. Take your body temperature on a cold day, then on a warm day; do you notice any difference?
4. Determine whether the body temperature is the same after violent exercise as it is before.

B. Production of heat.

1. How was heat produced in experiment **32**?
2. How is heat produced in your body?
3. Is light produced in the human body (as in **32**)?

35. Action of the Diaphragm and the Lungs.†

Procure a bell jar with an opening at the top for a stopper. Place a marble in the centre of a sheet of rubber, tie the rubber about it, and stretch the sheet of rubber over the larger end of the bell jar, tying tightly. Secure a rubber stopper (provided with two holes) which will fit the opening in the top of the bell jar. Tie a toy balloon to the end of a glass tube and pass the latter through one of the holes in the rubber stopper. Through the other hole pass a glass tube, attaching to the upper end a piece of rubber tubing closed with a clamp. Insert the rubber stopper in the opening at the top of the bell jar with the toy balloon within the jar.

The balloon represents a lung ; the glass tube to which it is tied, the windpipe ; while the bell jar itself represents the chest-cavity, and the sheet rubber the diaphragm.

A. Exhaust some of the air from the bell-jar by applying the mouth to the rubber tubing, and then replace the clamp.
   1. Is the pressure of air greater now within the bell jar or without?
   2. What is the effect on the sheet rubber of removing air from within the jar? Explain.
   3. How is the toy balloon affected? Why?

B. Seize the marble tied into the sheet of rubber and make the latter move up and down.
   1. Does the air within the bell jar have more or less room when the rubber is pulled down?
   2. Is the pressure within the glass jar greater or less than when the rubber diaphragm was pushed up into the glass bell jar?
   3. What is the effect on the rubber balloon of thus increasing the size of the cavity in which the balloon is hung? Why?

C. Application to the action of human diaphragm and lungs.
   1. In what respects does this model illustrate the process of inhaling and exhaling air in our own bodies?
   2. In what respects does the model fail to illustrate the process of respiration?

36. CIRCULATION OF AIR IN SCHOOLROOM.†

Materials: Concentrated hydrochloric acid, concentrated ammonia; evaporating-dishes.

Pour into an evaporating-dish some concentrated hydrochloric acid; into another dish pour some concentrated ammonia.

A. Bring the two dishes near together.
   1. What is the effect?
   2. Place the two dishes near the hot-water or steam-pipes. Describe the course of the fumes.
   3. Place the dishes near the opening to a ventilator. What course do the fumes take?
   4. Draw a diagram of the room and indicate by arrows the course of the moving air as demonstrated by the fumes.

B. Open a window, and place the two dishes near a steam-pipe near the window.
   1. Does the moving air take the same course as before?

2. Does the open window help or retard the ventilation of the room?

NOTE.—Gunpowder or flash-paper may be used instead of the acid and ammonia.

37. Inspired and Expired Air.

Materials: Thermometer, bottle fitted as described in C below; lime-water.

A. Difference in temperature.

1. Note on a thermometer the temperature of the air in the room.
2. Breathe for a few seconds on the bulb of the thermometer. Note temperature.
3. What is the difference in temperature between inspired and expired air?

B. Difference in amount of moisture.

1. Breathe again upon the polished bulb of the thermometer. Describe result.
2. What substance is thus shown to be one of the wastes excreted by the lungs?

C. Differences in chemical composition.

Secure a bottle fitted with a rubber stopper with two holes. Through one hole in the stopper pass a glass tube (No. 1) until it reaches nearly to the bottom of the bottle. Pass the end of another tube through the other hole, allowing the tube to project but a short distance into the bottle; attach a piece of rubber tubing to the upper end of this tube (No. 2). Half-fill the bottle with clear-lime water and insert the stopper.

1. Apply the mouth to tube No. 2, exhausting the air from the bottle. Describe result.
2. Draw into the lungs through the lime-water a considerable quantity of air in this way. Does any change take place in the lime-water?
3. Does inspired air contain a large amount of carbon dioxide?
4. Apply the mouth to tube No. 1 (which passes below the level of the lime-water). Expel the air from the lungs through the lime-water. Describe any changes in the lime-water.
5. What is your inference from 4?

D. Name three differences between inspired and expired air.

38. Study of the Skin.*

Materials: Clean needle; printer's or mimeograph ink.

A. Epidermis.

1. Wash the hands thoroughly in warm water, then dry them; rub together the palms and fingers of both hands briskly for a moment. What do you see on your hands as the result? (This material was a part of your non-living epidermis.)
2. Run the point of a clean needle beneath the thin outer layer of the skin on the palm of the hand.
   a. Does the needle cause blood to flow?

Is the outer layer of skin (epidermis) supplied with blood-vessels?

b. Does the insertion of the needle cause any pain? Can you feel the point of the needle touch the skin? Would you infer that nerves entered the epidermis or not?

3. In what regions of the surface of the hand is the epidermis thickest? How do you know? In what region is it thinnest?
4. Press the tip of the forefinger on a piece of cloth covered with some thick ink (printer's ink or mimeograph ink is best), then press the finger-tip on a page in your note-book. Study the impression made.

   a. Are the black lines (made by the ridges on the finger) all of the same width? Are they all parallel to one another?

   b. In the same way take the impression of the tips of your other fingers and of your thumb. In what respects do these various impressions differ?

   c. Where else on your hand can you see similar ridges?

   d. What other lines are visible on the palm of the hand?

B. Hair.

1. On what portions of the hand is hair found? Where is it wanting?
2. Compare the hair on the surface of your hand with that on the hand of an older person. What difference do you note?

3. Do blood-vessels run into the hair? How do you know?
4. Which part of the hair is supplied with nerves? How do you know?

C. Nails.

1. What different areas do you notice in your thumb-nail? How do they differ in appearance?
2. Make a drawing of your thumb-nail, showing these different regions.
3. Scrape off a little of the outer surface of the nail; does this cause blood to flow? Are nails supplied with blood-vessels?

D. Deeper layers of the skin.

1. With the thumb and forefinger of the right hand grasp a portion of the skin on the back of the left hand. Can you lift the skin from the muscles and tendons lying below?
2. In the same way determine whether the skin on the palm of the hand and on the fingers is closely or loosely attached to the underlying tissue. What do you find to be true?
3. Determine the effect of pushing a clean needle point a little distance into the tissue lying beneath the epidermis.
   (*a*) Is the under skin (dermis) supplied with blood-vessels? How do you know?
   (*b*) Is the dermis supplied with nerves? How do you know?

E. Blood system in the skin.

1. Press the finger of the right hand on the back of the left hand; quickly remove the finger. What difference do you note in the color of the spot pressed and in the skin about this spot? Give an explanation of this difference.
2. From the preceding experiment can you explain the cause of sudden paleness in the face?
3. State the difference in the relative quantity of blood flowing through the cheek when it is flushed and when it is pale.

39. Study of the Kidney of the Sheep.

Materials: Fresh kidneys of sheep or pig in capsule, prepared for the pupil as follows: Slit the capsule on convex side enough to allow the kidney to be removed; cut the kidney from the convex border toward the hilum sufficiently to open up the cavity within; replace the kidney within the capsule; probe.

A. Exterior of the kidney.

1. Describe the capsule by which the kidney is surrounded.
2. Carefully remove the kidney from the capsule, taking care not to tear the latter. Where is the capsule attached to the kidney?
3. What is the shape of the kidney?
4. What is the color of the kidney. Why?

5. How many tubes can you find connected with this organ? Can you suggest the use of any of these tubes? (The depression in the kidney to which the tubes pass is called the hilum.)

B. Gross structure of the kidney.

1. Pull apart the halves of the kidney sufficiently to look within.
2. What is the shape of the cavity near the hilum (sinus of the kidney)?
3. By means of a probe locate the tube (ureter) which passes out from this cavity.
4. The layer on the outside of the kidney section is called the cortical layer.
   a. Does this layer anywhere reach down to the sinus?
   b. What characteristics distinguish the cortical layer from the rest of the solid portion of the kidney?
5. The bodies which form the medullary portion of the kidney within the cortical layer are called the pyramids of Malpighi.
   a. Why is the name pyramid given to them?
   b. Do these pyramids project into the sinus of the kidney?
   c. Press one of the pyramids of Malpighi. Can you see any substance ooze out?

40. Study of Excretion.*

A. Excretion from sensible perspiration.
1. Find the exact weight of your body immediately after breakfast. Record the figure.
2. Exercise vigorously for several hours without eating or drinking.
3. Find again the weight of the body. Do you note any difference in weight?

B. Excretion from insensible perspiration.
1. Lay the palm of your hand (when your body feels cool) on a cold mirror. What evidence do you find of the activity of the skin?
2. Lay the back of your hand on the mirror.
   a. Do you find any difference between the amount of perspiration from the palm and from the back of the hand?
   b. Study your hand on a hot day and answer the same question.

41. Sensations of Touch.*

Materials: Pen and ink, pin, ruler, pair of scissors.

A. Blindfold a person, touch lightly some portion of his body with a pen dipped in ink, and ask him to point out with a pin the point touched, as soon as you have removed the pen.
1. Measure the distance with a ruler between the ink-dot and the point touched with the pin. Record result as directed below in 4.

2. Try the experiment several times on the same region of the body. Do the results agree?
3. Try the experiment on different parts of the body.
4. Record results in tabular form as follows:

Part of body experimented upon.	Distance between points.		
	1st trial.	2d trial.	3d trial.

B. Apply lightly the points of a pair of scissors (separated about a quarter of an inch) to the palm of your hand.
1. Can the points be felt as two, or do they feel as one?
2. Separate the points of the scissors a little more than a quarter of an inch, and apply again. At what distance apart can the points be felt as two?
3. In the same way determine at what distance apart the points can be felt as two on the tip of the middle finger, on the tip of the tongue, on the back of the neck, on the back of the hand.
4. Record your results in tabular form as follows, placing the smallest distance first, and arranging the distances in order from smallest to greatest.

Part of body experimented upon.	Distance between points.

5. Apply the points of the scissors at the upper part of the arm, near the elbow, at the

wrist and on the palm, noting at what distance apart the points are felt as two.

a. Is the distance greater as you approach the shoulder or as you near the hand?

b. Does it make any difference whether the points are applied in transverse or in longitudinal axis of the arm?

C. Cross the middle finger of the hand over the forefinger, and rub the tips of these two fingers against the point of your nose at the same time. What impression do you receive in regard to your nose?

42. Sensations of Taste and Smell.*

Materials: Potato, onion, apple, spices, flavoring extracts, sugar, salt, mustard, quinine solution, vinegar.

A. Flavors of substances.

1. Secure a bit of potato, a bit of onion, and a bit of apple; close your eyes and hold your nose tightly; place each of the three in your mouth successively. Can you distinguish by taste one piece from the others?

2. Keeping the eyes closed, repeat the experiment without holding the nose.

   a. Can the foods be distinguished now?

   b. What do these experiments teach you in regard to the real nature of what is commonly thought to be the taste of certain foods?

   c. Why are many foods tasteless to a person with a cold in the head?

d. What method of taking disagreeable medicines is suggested by these experiments?

3. Close your eyes and hold your nose; experiment with spices, sugar, salt, mustard, quinine solution, vinegar, peppermint, vanilla, etc. Record your results as follows:

Substances distinguished by taste alone.	Substances distinguished by taste and smell.

B. Wipe the tongue dry and place upon it a bit of sugar.

1. Can the sugar be tasted?
2. To what condition must foods be brought in order to be tasted?
3. What use of the saliva in the mouth does this suggest?
4. Give a reason which may explain why sand is tasteless?

C. Localization of taste sensations on the tongue.

1. Place a bit of sugar on the tip of the tongue; another bit on the back of the tongue.
   a. In which case is the sweet taste more distinct?
   b. Determine whether sweet substances are tasted more distinctly along the middle of the tongue or at the edge.
2. By using a bit of salt determine in the same way what region of the tongue is most affected by saline substances.

3. Prepare a strong solution of quinine by dissolving sulphate of quinine in water by the aid of sulphuric acid. Determine what portion of the tongue is most sensitive to bitter substances; the portion which is least sensitive.
4. Test the various portions of the tongue with vinegar.
5. Record your results as follows:

Kind of substance.	Part most affected.	Part least affected.
Sweet...........		
Sour............		
Bitter...........		
Salt.............		

43. Study of Yeast.*

Materials for home work: Compressed yeast, molasses; two pint bottles, small bottle; refrigerator; stove; thermometer.

Materials for class demonstrations: (A, 9, 10, D); Flask, rubber cork (two holes); U-tube, test-tube; chemical thermometer; glass- and rubber-tubing; water bath; condenser; compound microscope (500 diameters), slide; cover-glass; lime-water, eosin or methyl violet.

A. Study of the growth of yeast.

Mix about an eighth of a cake of compressed yeast in a tablespoonful of water and stir until a smooth thin mixture is formed. Add this to about a half-pint of water in which a tablespoonful of molasses has been dissolved. Place this mixture in a wide-mouthed bottle which holds about a pint; stopper very loosely.

1. State in your note-book the color of the mixture. Does it appear clear or muddy?
2. What is the smell and taste of the mixture?
3. Place the liquid where the temperature is 70° to 90° F. Determine the exact temperature by the use of a thermometer, and record it.
4. At the end of several hours examine the liquid. What evidence is there that the yeast is "working"?
5. Determine the effect of temperature on the working of yeast in the following manner:
   a. Shake up the mixture when it is working well, and pour some off into a small bottle; immerse the latter up to its neck in ice-water for an hour, or place it in a refrigerator.
      (1) What is the effect on the activity previously noticed in the liquid?
      (2) Warm the liquid again to the temperature of the room and record result.
      (3) Yeast is a plant. Has it been killed by the cold? Give reason for your answer.

   b. Fill the small bottle again with some more of the working yeast mixture; place it on the stove and boil it, taking care not to break the bottle. Allow the mixture to cool to the temperature of the room.
      (1) What effect does boiling have on the activity of the yeast?

(2) Keep the mixture for a day or two. Was the yeast killed by the heat?

c. Summary.

(1) What temperature do you find to be most favorable for the growth of yeast?

(2) What is the effect of extreme cold?

(3) What is the effect of a high degree of heat?

6. At the end of 24 hours smell the mixture of molasses and yeast remaining in your large bottle. How does it differ from that observed in 2?

7. Taste of the liquid at the same time. Compare with result obtained in 2.

8. What differences do you note in the color or in the general appearance of the mixture since the experiment was begun? (Compare with observations in 1.)

† 9. Pour some of the yeast mixture which is working well into a glass flask. Insert a rubber cork in the mouth of the flask through which passes one arm of a U-tube. Half-fill a test-tube with lime-water. Allow the free end of the U-tube to dip below the surface of the lime-water. Be sure all the connections are tight. Set the apparatus aside in a warm place for a few hours.

a. What change has taken place in the lime-water?

b. What kind of gas is produced by the growth of yeast?

†10. Pour into another flask some of the yeast mixture which has been working for some time. Procure a rubber stopper with two holes. Through one hole pass the bulb of a chemical thermometer so that it reaches half-way down to the bottom of the flask. Through the other hole pass a glass tube, allowing it to project just inside the flask. Connect this glass tube with rubber tubing to a condenser (used in distillation). Place the flask over a water-bath, and keep the temperature at the point where the thermometer registers 78° C. Collect the liquid which comes from the condenser.

a. What is the smell and taste of the liquid?

b. Apply a lighted match to a little of it. Will it burn?

c. What kind of substance is formed when yeast "works," or when fermentation takes place?

B. Into a half-pint of water put a spoonful of the thin yeast mixture (of yeast and water); set aside in a warm place beside the other mixture. Examine at the end of 24 hours.

1. Do you see any evidence of activity in the mixture?
2. What kind of substance was present in the preceding experiments which is absent in this experiment?
3. What do you infer from this experiment?

C. Summary.

1. What conditions are necessary for the rapid growth of yeast?
2. What changes are caused by the yeast in a mixture in which it is growing?
3. What substances are produced by the growth of yeast?

D. Microscopic study of yeast. (In class.)

By means of a pipette put a drop from the bottom of a yeast mixture on a glass slide; cover with a thin cover-glass, and examine under the high power of the microscope.

1. What is the color of the solid bodies (yeast-cells) which you see?
2. Yeast-cells form new cells by budding, the bud (daughter-cell) usually remaining attached to the cell (mother-cell) which produced it.
   a. Draw a group of cells showing a mother-cell and two daughter-cells.
   b. Draw a group of cells showing a mother-cell, two daughter-cells, and two grand-daughter-cells.
3. Can you distinguish a nucleus in any of the yeast-cells?
4. Place a drop of stain (eosin or methyl violet) on the slide at the edge of the cover-glass, allowing it to run beneath the glass to stain the cells. Can you make out any further facts regarding the structure of yeast?

44. Study of Bacteria.

Materials for home work (C): Three bottles (two provided with stoppers), ice-box, thermometer; pint of milk.

Materials for class-room work (A, B, D): Flask, hot-water filter, beaker, Petri-dishes, cotton-wool, needle, compound microscope (500 diameters) slide, cover-glass; 60 gr. gelatin, 1 lb. lean beef, 6 gr. peptone, 6 gr. salt, caustic potash, methyl violet, corrosive sublimate solution (1:1000).

A. Study of the growth of bacteria.

"Nutrient gelatin, most useful for the growth of all kinds of bacteria, is prepared in this way:

"One pound of lean beef is cut up, to it is added one pint of water, and is kept boiling in the digestor or any other vessel for from half to three quarters of an hour. After having been strained through fine calico it is filtered through paper into a beaker; bring up by adding water to 600 ccm.; add to this 60 grams of the finest gold-label gelatin cut up in small pieces, 6 grams of peptone, and 6 grams of common salt. Dissolve on water-bath, but do not let the water boil; neutralize with carbonate of soda or, better, with liquor potassæ till faintly alkaline; boil for half an hour, filter by hot filter into a sterile flask plugged with sterile cotton-wool, and bring it up to boiling-point, at which it is kept for a few minutes. This can be kept as stock gelatin."—Klein, "Micro-Organisms and Disease," Macmillan & Co. (For further directions refer to this or other books on bacteriology.)

Pour some of the nutrient gelatin into several

Petri dishes which have been sterilized, quickly replacing the covers on the dishes, also the cotton plug in the flask. Number the dishes 1, 2, etc., and write date of each part of the experiment.

Keep some of the dishes carefully closed throughout the experiments. Label each of these dishes "Not exposed."

Open several of the other dishes, exposing the gelatin to the air of the room for one-half minute. Replace the covers, and label each dish "Exposed to the air one-half minute."

Open other dishes sufficiently to spread on the surface a little of the dust from the floor or from the street. Label each dish "Exposed to dirt."

Open a third set of dishes of the gelatin and pour on the surface a very little of the city water obtained from the school faucets. Label each "Exposed to city water."

Set aside the dishes where the temperature is about 70° F. Examine the dishes at the end of a day or two.

1. Do you find any differences between the dishes which have been exposed to the air, the dirt, and the water, and those which have not been exposed?
2. Draw a figure of the dish you are studying, representing carefully the form and size of the spots (colonies of bacteria or mould).
3. Study the same dish several days later. Make a careful drawing as in 2 above.

Have the colonies changed in size or appearance since your last study?

4. Describe the color of the colonies.
5. Do any of the colonies appear to affect the gelatine around them?

B. Microscopic study of bacteria.

Carefully lift the cover from one of the plates of gelatin which has been exposed. Touch one of the colonies of bacteria with the point of a needle, and then rub the needle-point on a clean glass slide; add a drop of water to the spot touched by the needle, and cover with a cover-glass. Examine with the highest powers of the microscope.

1. What is the color of the tiny bodies (bacteria) which you see?
2. Do you find more than one kind of bacteria? If so, what is the shape of each?
3. Do any of the bacteria seem to be in motion?
4. Place a drop of stain (methyl violet or eosin) at the side of the cover-glass and allow it to run beneath the glass, staining the cells. Can you make out any further points of structure in the bacteria?

C. Growth of bacteria in milk (at home).

Secure three clean bottles of about the same size, two of them provided with stoppers.

Into one of the bottles pour some good fresh milk; cover and place in the ice-box, or in some other cold place. Label the bottle "No. 1."

Pour into the second bottle about the same amount of milk, and set it aside in a moderately warm place, leaving it uncorked. Note the temperature by means of a thermometer. Label "No. 2."

Clean the third bottle and the cork in boiling water. Boil some of the milk 15 minutes, and pour it into the bottle while hot. Cork the bottle and place it beside the second bottle. Label "No. 3, Sterilized milk."

Examine the three bottles of milk at the end of 12 hours.

1. Do you notice any difference in the smell or taste of No. 1, No. 2, and No. 3?
2. Boil the milk in bottle No. 3 again; clean the bottle and cork in boiling water as before, and replace the milk in the bottle; cork the bottle. Put bottle No. 1 back in the ice-box; return bottles No. 2 and No. 3 to the place from which you took them.
3. Examine all three bottles at the end of a second 12 hours. Have any further changes taken place?
4. Carry out the directions given in 2 above a second time. Repeat your examinations at the end of each successive 12 hours for two or three days, each time boiling the milk in bottle No. 3. Record in your notebook each time the changes which you observe in each of the bottles.
5. The changes in the milk are caused by the growth of bacteria from the air or on the bottles or stoppers.

a. What effect does a cold temperature have on the growth of bacteria?

b. What effect does boiling have on the growth of these cells?

c. What is the most favorable temperature for the growth of bacteria?

d. What effect do some bacteria have on the milk?

e. Compare the results obtained in this experiment with those already obtained in the experiment with yeast.

D. Sterilization.

Prepare three dishes of nutritive gelatin as directed above.

Remove the cover from No. 1, and allow it to remain exposed to the air for several minutes. Label it "Gelatin No. 1."

Remove the cover from a second dish, expose it as in No. 1; then pour over the surface a thin film of corrosive sublimate (1 : 1000). Replace the cover and label "Gelatin No. 2 + Poison."

Expose a third dish of gelatin to the air for the same length of time as in No. 1 and No. 2. Heat this dish for a half-hour every 12 hours in a steam sterilizer or over a water-bath. Label "Heated Gelatin." Keep all three dishes covered, and set them aside where the temperature is about 70° F.

Compare the three dishes at the end of three days.

1. What differences do you note between the three dishes?

2. What is the effect of the poison (corrosive sublimate) on the growth of bacteria?
3. What effect does heating and cooling have on the growth of bacteria?
4. In what two ways may a substance be sterilized?

E. From all your experiments state—
1. What conditions seem to favor the growth of bacteria?
2. What conditions seem to hinder the growth of bacteria?

F. Practical questions in bacteriology.
1. Why are fruits cooked before canning?
2. Why should fruit-jars be filled completely before screwing on the cover?
3. Why do fruit-jars sometimes burst long after being filled?
4. Why is grass dried before putting in the barn?
5. Why are milk, meat, etc., put in the refrigerator in summer-time?
6. Why should the prohibition against spitting in public places be rigidly enforced?
7. Why should sweeping be done so far as possible without raising a dust?
8. Why are hard-wood floors more healthful than carpets.
9. Why should the teeth be brushed often?
10. Why should the refuse be removed from the streets every morning early, especially in summer-time?
11. Why should sink-drains be carefully inspected?

12. Why should wounds be carefully cleansed and dressed at once?
13. Why are typhoid fever, diphtheria, and other infectious diseases often better treated in hospitals?
14. In what ways do bacteria prove to be of benefit to mankind?
15. In what ways do they prove to be "man's invisible foes"? (Read "The Story of Bacteria," "Dust and its Dangers," "Drinking-water and Ice Supplies, and their Relations to Health and Disease," by T. M. Prudden, M.D. Published by G. P. Putnam's Sons.)

45. Comparative Study of the Mammalian Skeleton.

(At the American Museum of Natural History, 8th Ave. and 77th St.)

Note.—The skeletons of the lion, horse, seal, musk-ox, sea lion, and elephant are among those best adapted for observation.

A. Spinal Column:

1. How many vertebræ are found in the neck (cervical) region?
2. How many vertebræ bear ribs (dorsal vertebræ)?
3. How many vertebræ in the lumbar region?
4. Can you determine how many vertebræ have united to form the sacrum?
5. How many vertebræ in the tail (caudal vertebræ)?

6. In what regions of the spinal column are curves noticeable? How do they differ from the curves in the human skeleton?
7. Are spinous processes specially developed in any region? Can you suggest any reason for this?

B. Ribs and sternum.

8. How many ribs has the animal?
9. How many are attached to the sternum?
10. Is the sternum a single piece of bone? If not, of how many parts does it seem to consist?

C. Anterior appendage.

11. Can you distinguish a shoulder-blade (scapula)?
12. Has the animal a collar-bone (clavicle)?
13. Is the humerus relatively long or short compared with the whole appendage?
14. What is the relative size of radius and ulna?
15. Is it probable that rotation of the radius about the ulna is possible?
16. Is the projection ("funny-bone") on radius or ulna?
17. How many wrist-bones (carpals) in the anterior appendage?
18. Does the animal walk on the palm of the hand or on the tips of the fingers?
19. How many fingers (or toes) of anterior appendage does it use?
20. How many bones are there in each finger?
21. Is a thumb distinguishable?
22. What use does the animal make of the anterior appendages?

D. Posterior appendage.

23. Is a knee-cap (patella) distinguishable?
24. What is the relative size of tibia and fibula?
25. How many ankle-bones (tarsals) are found in the posterior appendage?
26. How many toes of the posterior appendage does the animal use?
27. Does the animal seem to be adapted for swift or for slow locomotion? Give reasons for your answer.

E. Teeth.

28. What is the dental formula (number of incisors, canines, grinders in each half-jaw)?
29. Did the animal probably eat animal or vegetable food? Reason for answer.

46. Rules for the Use of the Compound Microscope.

I. *To lift the microscope,* always grasp it firmly by the pillar beneath the stage.

II. *To use the low power objective.*

1. Place the stand so the two arms of the foot face the window. Keep the microscope out of the direct sunlight.
2. See that the nose-piece is in the position which will bring the low-power objective over the opening in the stage.
3. Move the tube up or down by the rack and pinion until the lower end of the low-power

objective is a little more than a quarter of an inch above the level of the stage.

4. See that the plane side of the mirror is facing the source of light. Looking down through the tube, move the mirror about until the field of the microscope has the best possible illumination. (The field of the microscope is the lighted circular area which appears when looking down through the tube.)
5. Place the slide on the stage (cover-glass on top) in a position so the object to be examined is over the centre of the hole in the stage. Fix the slide in place with the clips.
6. Look through the microscope, and slowly move the tube up by turning the rack and pinion until the object is seen as clearly as possible. Be careful *never* to push the tube down so the objective touches the slide.
7. In examining a slide, focus the tube by means of the fine adjustment-screw. When the screw is turned in a direction like the hands of a clock, the objective is lowered; when turned in the opposite direction, the objective is raised from the slide.

III. *To use the high-power objective.*

1. Place the slide upon the stage and focus upon it with the *low-power* objective as directed in II above.

2. Turn the mirror so the concave surface faces upward. Looking through the tube, move the mirror about until the field of the microscope has the best illumination.
3. Place the eye at the level of the stage and carefully turn the nose-piece so the high-power objective is brought into position above the hole in the stage. If the lower end of the objective touches the cover-glass, turn the fine adjustment-screw in a direction opposite to that of the hands of a clock.
4. When the objective is in position look at the object through the microscope, and focus slowly with the *fine adjustment-screw* until the image is clearest. Take great care as directed in 3 above to see that the objective does not touch the cover-glass.
5. After using the high-power objective, turn the nose-piece so as to leave the low-power objective in position over the diaphragm.

IV. The pupil should learn to look through the microscope with both the right and the left eye. Both eyes should always remain open.

V. Approximate magnifications of the Bausch and Lomb microscopes.

1. 2-inch objective with 2-inch eye-piece magnifies about 15 diameters.
2. 2-inch objective with 1-inch eye-piece magnifies about 30 diameters.
3. $\frac{3}{8}$-inch objective with 2-inch eye-piece magnifies about 50 diameters.

4. $\frac{2}{3}$-inch objective with 1-inch eye-piece magnifies about 100 diameters.
5. $\frac{1}{6}$-inch objective with 2-inch eye-piece magnifies about 250 diameters.
6. $\frac{1}{6}$-inch objective with 1-inch eye-piece magnifies about 450 diameters.

List of Apparatus and Chemicals required to Supply a Class of 24.

Articulated Skeleton, $25 (may be obtained of The Kny-Scheerer Co., 17 Park Place, New York City).

Joint apparatus devised by Dr. G. W. Fitz of Harvard University, $5 (may be obtained of H. Sumner, Wood Avenue, Hyde Park, Mass).

The following supplies will be furnished to schools by Bausch & Lomb, 1123 Broadway, New York City, at the special prices quoted. (The numbers and letters refer to Bausch & Lomb's Catalogue.)

1 Compound Microscope, AAB1, ⅔–⅙″	$25 60
24 Magnifiers, 5-10″ diameter, QR	8 00
1 Weighing Balance, No. 7120	13 50
24 Evaporating Dishes (porcelain), No. 4430, 50 cc.	2 70
24 Alcohol Lamps, No. 3693 c., 100 cc	7 50
1 Gross Slides (3×1″), No. 7315.	0 64
1 oz. Round Cover-glasses, ¾″, No. 2	75
24 Scalpels, No. 5480	4 50
24 Pairs Forceps, straight, No. 5850	4 50
50 Dissecting Needles, No. 5950	1 57
72 Test-tubes, 150×16 mm., No. 3905	1 12
1 Chemical Thermometer, No. 8735B	94
1 Lactometer, No. 3754	38
12 Iron Apparatus Stands, No. 5095, 3 rings	9 00
24 Pieces Wire Gauze, 3×3″, No. 5215 per lb.	38
24 Glass Stirring-rods, No. 4566	90
10 Ft. Glass Tubing, 5 mm., No. 4560	38
1 Thistle-tube, No. 4020, 30 mm.	09
24 Beaker Glasses, 98 mm., No. 4395	3 00
1 Glass Bottle, 3 oz., provided with rubber cork, 2 perforations. No. 4320, cork No. 5295	10
1 Bell Jar with opening at the top, 180 × 100 mm., No. 4510.	75
1 Piece of Sheet Rubber	15
2 Florence Flasks, 250 cc., No. 3850	26
1 Hot-water Filter, No. 4005	$3 00
12 Petri Dishes, 80 mm., No. 3802	1 80

CHEMICALS.

⅛ lb. Hydrochloric Acid (C.P.), 500 cc	24
⅛ lb. Nitric Acid (conc.), C.P., 500 cc., No. 7767	26
⅛ lb. Ammonia (conc.), C.P., 500 cc., No. 7767	12
¼ lb. Sulphuric Acid, No. 7769, 500 cc	24
1 oz. Iodine, No. 7732	38
5 oz. Potassium Iodide, No. 7753	1 50
¼ lb. Ether Sulphuric, 250 cc., No. 7775	82
5 gr. Caustic Potash	12
5 gr. Caustic Soda	12
100 cc. Lime-water	12
100 Pieces of Red Litmus-paper, 2 × ¼″, No. 7600	08
4 gr. Quinine	12
500 cc. 95% Alcohol, No. 7783	51
100 cc. Glycerin, No. 7790	26
5 gr. Pancreatin (Fairchild)	06
5 gr. Ox-gall	12
5 gr. Pepsin	12
10 gr. Common Salt.	05
1 gr. Phosphate of Lime.	12
10 gr. Glucose	12
500 cc. Fehling solution, No. 7776	1 50
10 gr. Eosin, No. 7874	26
10 gr. Methyl Violet, No. 7896	26
1 lb. Gelatin, No. 7847	68
12 gr. Peptone	10

November 1898

SCIENCE
REFERENCE AND TEXT-BOOKS

PUBLISHED BY

HENRY HOLT & COMPANY, 29 WEST 23D ST. NEW YORK

---

*Books marked * are chiefly for reference and supplementary use, and are to be found in Henry Holt & Co.'s List of Works in General Literature. For further particulars about books not so marked see Henry Holt & Co.'s Descriptive Educational Catalogue. Excepting* JAMES' PSYCHOLOGIES, WALKER'S POLITICAL ECONOMIES, *and* ADAMS' FINANCE, *all in the American Science Series, this list contains no works in Philosophy or Economics. Postage on net books* 8 *per cent. additional.*

American Science Series

1. **Astronomy.** By SIMON NEWCOMB, Professor in the Johns Hopkins University, and EDWARD S. HOLDEN, Director of the Lick Observatory, California. *Advanced Course.* 512 pp. 8vo. $2.00 *net.*
   The same. *Briefer Course.* 352 pp. 12mo. $1.12 *net.*
2. **Zoology.** By A. S. PACKARD, Jr., Professor in Brown University. *Advanced Course.* 722 pp. 8vo. $2.40 *net.*
   The same. *Briefer Course.* (*Revised and enlarged*, 1897.) 338 pp. $1.12 *net.*
   The same. *Elementary Course.* 290 pp. 12mo. 80 cents *net.*
3. **Botany.** By C. E. BESSEY, Professor in the University of Nebraska. *Advanced Course.* 611 pp. 8vo. $2.20 *net*
   The same. *Briefer Course.* (*Entirely new edition*, 1896.) 356 pp. $1.12 *net.*
4. **The Human Body.** By H. NEWELL MARTIN, sometime Professor in the Johns Hopkins University.
   Advanced Course. (*Entirely new edition*, 1896.) 685 pp. 8vo. $2.50 *net.*
   Copies without chapter on Reproduction sent when specially ordered.
   The same. *Briefer Course.* (*Entirely new edition revised by Prof. G. Wells Fitz*, 1898.) 408 pp. 12mo. $1.20 *net.*
   The same. *Elementary Course.* 261 pp. 12mo. 75 cents *net.*
   The Human Body and the Effect of Narcotics. 261 pp. 12mo. $1.20 *net.*
5. **Chemistry.** By IRA REMSEN, Professor in Johns Hopkins University. *Advanced Course.* (*Inorganic entirely new edition*, 1898.) 850 pp. 8vo. $2.80 *net.*
   The same. *Briefer Course.* (*Entirely new edition*, 1893.) 435 pp. $1.12 *net.*
   The same. *Elementary Course.* 272 pp. 12mo. 80 cents *net.*
   Laboratory Manual (*to Elementary Course*). 196 pp. 12mo. 40 cents *net.*
   Chemical Experiments. By Prof. REMSEN and Dr. W. W. RANDALL. (*For Briefer Course.*) *No* blank pages for notes. 158 pp. 12mo. 50 cents *net.*
6. **Political Economy.** By FRANCIS A. WALKER, President Massachusetts Institute of Technology. *Advanced Course.* 537 pp. 8vo. $2.00 *net.*
   The same. *Briefer Course.* 415 pp. 12mo. $1 20 *net.*
   The same. *Elementary Course.* 423 pp. 12mo. $1.00 *net.*
7. **General Biology.** By Prof. W. T. SEDGWICK, of Massachusetts Institute of Technology, and Prof. E. B. WILSON, of Columbia College. (*Revised and enlarged*, 1896.) 231 pp. 8vo. $1.75 *net.*
8. **Psychology.** By WILLIAM JAMES, Professor in Harvard College. *Advanced Course.* 689 + 704 pp. 8vo. 2 vols. $4.80 *net.*
   The same. *Briefer Course.* 478 pp. 12mo. $1.60 *net.*
9. **Physics.** By GEORGE F. BARKER, Professor in the University of Pennsylvania. *Advanced Course.* 902 pp. 8vo. $3.50 *net.*
10. **Geology.** By THOMAS C. CHAMBERLIN and ROLLIN D. SALISBURY, Professors in the University of Chicago. (*In Preparation.*)
11. **Finance.** By HENRY CARTER ADAMS, Professor in the University of Michigan. *Advanced Course.* xiii + 573 pp. 8vo. $3.50 *net.*

Allen's Laboratory Exercises in Elementary Physics. By CHARLES R. ALLEN, Instructor in the New Bedford, Mass., High School. *Pupil's Edition:* x + 209 pp. 12mo. 80c., *net.* *Teachers' Edition;* $1.00, *net.*

Arthur, Barnes, and Coulter's Handbook of Plant Dissection. By J. C. ARTHUR, Professor in Purdue Univ., C. R. BARNES, Professor in Univ. of Wisconsin, and JOHN M. COULTER, President of Lake Forest University. xi + 256 pp. 12mo. $1.20, *net.*

Atkinson's Elementary Botany. By GEO. F. ATKINSON, Professor in Cornell. For beginners. Fully illustrated.

Barker's Physics. See American Science Series.

Barnes' Plant Life. By C. R. BARNES, Professor in University of Chicago. Illustrated. x + 428 pp. 12mo.

Beal's Grasses of North America. For Farmers and Students. By W. J. BEAL, Professor in the Michigan Agricultural College. 8vo. Copiously Ill'd. Vol. I., 457 pp. $2.50, *net.* Vol. II., 707 pp. $5, *net.*

Bessey's Botanies. See American Science Series.

Black and Carter's Natural History Lessons. By GEORGE ASHTON BLACK, Ph.D., and KATHLEEN CARTER. (For very young pupils.) x + 98 pp. 12mo. 50c., *net.*

Bumpus's Laboratory Course in Invertebrate Zoology. By H. C. BUMPUS, Professor in Brown University. Revised. 157 pp. 12mo. $1, *net.*

Cairns's Quantitative Chemical Analysis. By FRED'K A. CAIRNS. Revised and edited by Dr. E. WALLER. 417 pp. 8vo. $2, *net.*

Champlin's Young Folks' Astronomy. By JOHN D. CHAMPLIN, Jr., Editor of *Champlin's Young Folks' Cyclopædias.* Illustrated. vi + 236 pp. 16mo. 48c., *net.*

Congdon's Qualitative Analysis. By ERNEST A. CONGDON, Professor in Drexel Institute. 64 pp. Interleaved. 8vo. 60c., *net.*

Crozier's Dictionary of Botanical Terms. 202 pp. 8vo. $2.40, *net.*

Hackel's The True Grasses. Translated from "Die natürlichen Pflanzenfamilien" by F. LAMSON-SCRIBNER and EFFIE A. SOUTHWORTH. v + 228 pp. 8vo. $1.50.

Hall's First Lessons in Experimental Physics. For young beginners, with quantitative work for pupils and lecture-table experiments for teachers. By EDWIN H. HALL, Assistant Professor in Harvard College. viii + 120 pp. 12mo. 65c., *net.*

Hall and Bergen's Text-book of Physics. By EDWIN H. HALL, Assistant Professor of Physics in Harvard College, and JOSEPH Y. BERGEN, Jr., Junior Master in the English High School, Boston. *Greatly enlarged edition.* 596 pp. 12mo. $1.25, *net.*

Postage 8% additional on net books. Descriptive list free.

Hertwig's General Principles of Zoology. From the Third Edition of Dr. Richard Hertwig's *Lehrbuch der Zoologie*. Translated and edited by GEORGE WILTON FIELD, Professor in Brown University. 226 pp. 8vo. $1.60 *net*.

Howell's Dissection of the Dog. As a Basis for the Study of Physiology. By W. H. HOWELL, Professor in the Johns Hopkins University. 100 pp. 8vo. $1.00 *net*.

Jackman's Nature Study for the Common Schools. (Arranged by the Months.) By WILBUR JACKMAN, of the Cook County Normal School, Chicago Ill. 448 pp. 12mo. $1.20 *net*.

Kerner & Oliver's Natural History of Plants. Translated by Prof. F. W. OLIVER, of University College, London. 4to. 4 parts. With over 1000 illustrations and 16 colored plates. $15.00 *net*.

Kingsley's Elements of Comparative Zoölogy. By J. S. KINGSLEY, Prof. in Tufts College. With abundant laboratory drill. 357 pp. 12mo. $1.20 *net*.

Macalister's Zoology of the Invertebrate and Vertebrate Animals. By ALEX. MACALISTER. Revised by A. S. PACKARD. 277 pp. 16mo. 80 cents *net*.

MacDougal's Experimental Plant Physiology. On the Basis of Oels' *Pflanzenphysiologische Versuche*. By D. T. MACDOUGAL, University of Minnesota. vi + 88 pp. 8vo. $1.00 *net*.

MacIoskie's Elementary Botany. With Students' Guide to the Examination and Description of Plants. By GEORGE MACLOSKIE, D.Sc., LL.D. 373 pp. 12mo. $1.30 *net*.

McMurrich's Text-book of Invertebrate Morphology. By J. PLAYFAIR MCMURRICH, M.A., Ph.D., Professor in the University of Cincinnati. vii + 661 pp. 8vo. *New Edition*. $3.00 *net*.

McNab's Botany. Outlines of Morphology, Physiology, and Classification of Plants. By WILLIAM RAMSAY MCNAB. Revised by Prof. C. E. BESSEY. 400 pp. 16mo. 80c. *net*.

Martin's The Human Body. See American Science Series.

***Merriam's Mammals of the Adirondack Region,** Northeastern New York. With an Introductory Chapter treating of the Location and Boundaries of the Region, its Geological History, Topography, Climate, General Features, Botany, and Faunal Position. By Dr. C. HART MERRIAM. 316 pp. 8vo. $3.50 *net*.

Newcomb & Holden's Astronomies. See American Science Series.

***Noel's Buz**; or, The Life and Adventures of a Honey Bee. By MAURICE NOEL. 134 pp. 12mo. $1.00.

Noyes's Elements of Qualitative Analysis. By WM. A. NOYES, Professor in the Rose Polytechnic Institute. 91 pp. 8vo. 80c. *net*.

Packard's Entomology for Beginners. For the use of Young Folks, Fruit-growers, Farmers, and Gardeners. By A. S. PACKARD. xvi + 367 pp. 12mo. *Third Edition, Revised*. $1.40 *net*.

Postage 8 *per cent additional on net books. Descriptive list free*

Packard's Guide to the Study of Insects, and a Treatise on those Injurious and Beneficial to Crops. For Colleges, Farm-schools, and Agriculturists. By A. S. Packard. With 15 plates and 670 wood-cuts. *Ninth Edition.* 715 pp. 8vo. $4.50 *net.*

—— **Outlines of Comparative Embryology.** By A. S. PACKARD. Copiously illustrated. 243 pp. 8vo. $2.00 *net.*

—— **Zoologies.** See American Science Series.

Perkins's Outlines of Electricity and Magnetism. By CHAS. A. PERKINS, Professor in the University of Tennessee. 277 pp. 12mo. $1.10 *net.*

Pierce's Problems in Elementary Physics. Chiefly numerical. By E. DANA PIERCE, of the Hotchkiss School. 194 pp. 12mo. 60c. *net.*

***Price's The Fern Collector's Handbook and Herbarium.** By Miss SADIE F. PRICE. 72 plates, mostly life-size, with guide. 4to. $2.25.

Randolph's Laboratory Directions in General Biology. 163 pp. 16mo. 80c. *net.*

Remsen's Chemistries. See American Science Series.

Scudder's Butterflies. By S. H. SCUDDER. 322 pp. 12mo. $1.20 *net.*

—— **Brief Guide to the Commoner Butterflies.** By SAMUEL H. SCUDDER. xi + 206 pp. 12mo. $1.00 *net.*

—— **The Life of a Butterfly.** A Chapter in Natural History for the General Reader. By S. H. SCUDDER. 186 pp. 16mo. 80c. *net.*

Sedgwick and Wilson's Biology. See American Science Series.

***Step's Plant Life.** By EDWARD STEP. Popular Papers on the Phenomena of Botany. 12mo. 148 Illustrations. $1.00 *net.*

Underwood's Our Native Ferns and their Allies. By LUCIEN M. UNDERWOOD, Professor in DePauw University. *Revised.* 156 pp. 12mo. $1.00 *net.*

Williams's Elements of Crystallography. By GEORGE HUNTINGTON WILLIAMS, late Professor in the Johns Hopkins University. x + 270 pp. 12mo. *Revised and Enlarged.* $1.25 *net.*

Williams's Geological Biology. An Introduction to the Geological History of Organisms. By HENRY S. WILLIAMS, Professor of Geology in Yale College. 8vo. 395 pp. $2.80 *net.*

Woodhull's First Course in Science. By JOHN F. WOODHULL, Professor in the Teachers' College, New York City.

I. Book of Experiments. xiv + 79 pp. 8vo. Paper. 50c. *net.*
II. Text-Book. xv + 133 pp. 12mo. Cloth. 65c. *net.*
III. Box of Apparatus. $2.00 *net* (*actual cost to the publishers*).

Zimmermann's Botanical Microtechnique. Translated by JAMES ELLIS HUMPHREY, S.C. xii + 296 pp. 8vo. $2.50 *net.*