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STUDENT'S MANUAL OF
EXERCISES IN ELEMENTARY
BIOLOGY

GRUENBERG — WHEAT

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STUDENT'S MANUAL OF EXERCISES IN ELEMENTARY BIOLOGY

BY

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TO THE STUDENT

In order to get the most value out of your study of living things it is necessary to keep a record of observations and ideas as you go along.

It is the purpose of this Manual to help you keep a systematic record, as well as to guide you in discovering the facts that you will need for the more important ideas. You will of course get more facts and more ideas than this Manual calls for. You will sometimes have to make notes on loose sheets of paper or in a plain composition book. You will find it helpful to make short abstracts of what you read in your textbook or in other books. You will find it well worth while to record demonstrations made in the laboratory by the teacher or by other students, and observations made at home, out of doors, or in the classroom, by yourself or by others.

Begin your work by dating it. Where work carries over from day to day, date every entry.

Read all the directions for an exercise through before doing any of the work, making sure that you understand what you are trying to find out and just what you are going to do.

Make your record as you go along instead of waiting until the work is completed. A large part of the value of a scientific record is in its being made while the observation is fresh in mind, before there is time to forget it or to confuse it with other observations.

With most of the exercises there are *questions to think about*. These questions are not meant to find out how much you already know, but to show you how our understanding grows by combining facts into bigger ideas, and how ideas are put to work. So in writing your answers it would be well to give your reasoning instead of merely your final conclusion or a simple *Yes* or *No*.

EDUCATION DEPT.

TO THE TEACHER

It is the purpose of this Manual to be of direct help to teachers and students of biology. It is not intended, however, to be an automatic instrument to be placed in the hands of students abandoned to their own resources and good fortune. It will be necessary for the teacher to plan the work in accordance with available material and with local conditions. There are more exercises than most classes will be able to finish; there will arise occasions when exercises suggested in the Manual for Teachers will appear more urgent than any here, and there will be other occasions when totally new exercises will be most appropriate. The exercises, like the topics in the "Elementary Biology," can most profitably be arranged in the order best suited to local conditions or to the interests of the teacher.

The exercises are varied in form. Some are strictly experimental; others are observational; some call for the collection and organization of facts already in the possession of the pupils or of the community, utilizing "what everybody knows." In every case the exercise is designed to be *a project in finding out something*, usually something more comprehensive and more significant than mere matters of fact. Accordingly the projects permit of a great variety of adaptations to the conditions and needs of different localities or students. There are home and field and community exercises as well as strictly laboratory exercises. Moreover, some of the "laboratory" exercises call for living material in the form of the students themselves, suggesting that biology can be something very immediate and intimate as well as exotic and objective. There is a wide choice of materials and equipment and also of execution.

Some of the exercises emphasize the need for large masses of data or the need for coöperation among many observers. In all cases the social aspects of science, both in the sense of its origins in common experience and in the sense of its application to common problems, will be readily brought to the mind of the students.

Although only a very few of the exercises are marked "Demonstration," many of the others will be best executed by the teacher or by a single student or group of students, with all the others making notes. In some cases the exercise may be divided into a number of projects assigned to as many individuals or committees.

Where for any reason it is not feasible to have all the students perform the required exercises at practically the same time, individual or group projects can be arranged for demonstration to the whole class. Assignments should be made well in advance, so that the responsible students or committees may have ample time for preparation. Projects thus presented before the class should be received most critically. The students should be encouraged to challenge methods and conclusions in a thoroughly rigorous fashion, not in the spirit of captious faultfinding, of quibbling, or of trapping one another, but in the spirit of intellectual caution. We must be jealously on guard against letting false or foolish ideas impose themselves upon us by means of solemn ceremonial that calls itself scientific because it is enacted in a laboratory with apparatus.

The questions offered in connection with most of the exercises are designed, as stated in To the Student, to stimulate thinking. Here the teacher should maintain toward the replies offered the attitude expressed by the query, What makes you say that? rather than the attitude of approval or disapproval as to their correctness. It is more important to get the student to formulate hypotheses, check them, and modify them than it is to have him find the "right" answer; and in many cases nobody knows the true answer, if there is one.

In handling the mass of materials and apparatus that are so essential for insuring a consistently objective treatment of problems, it is possible to get the students to assume nearly all of the burden. Boys and girls are glad to assist where definite tasks and responsibilities are provided. Students should be designated as curators for the different classes of materials—the collections of insects, of flowers, of fossils, and other materials assembled for the museum and laboratory. Other students may be assigned to keep various special records, such as weather charts, temperature records, bird calendar, and so on. Those skilled in lettering and drawing can assist by making charts and diagrams to be added to a growing collection for class use. Some students may be custodians of current clippings,

pictures, etc. for the bulletin boards, while others may take charge of pamphlets, reference books, and other special reading material.

In planning the sequence of exercises it is necessary on the one hand to consider the sequence in which the topics are to be studied, and on the other hand to guard against making the exercises mere busy work. Especially important here is the completion of certain exercises while the problems involved are still problems—that is, before the solutions are supplied by reading or discussion. In a few cases supplementary work and reading for students are suggested. Further suggestions will be found in the Manual for Teachers.

All the exercises in this Manual have been tried out in actual school experience. The authors are nevertheless deeply indebted for valuable criticisms and suggestions to Dr. Bertha M. Clark of the William Penn High School, Philadelphia; Mr. Paul B. Mann of the Evander Childs High School, New York; Dr. A. J. Goldfarb, College of the City of New York; and Dr. W. H. D. Meier of the State Normal School, Framingham, Massachusetts, who have read the manuscript or the proof and have given us the benefit of their wide experience.

B. C. G.
F. M. W.

LIST OF EXERCISES

As each exercise is completed, write the date before the number on this list. This will help you check off your work.

EXERCISE	EXERCISE
_____ 1. CHANGES OCCURRING AROUND US	_____ 39. DIFFUSION OF GASES
_____ 2. SOME COMMON PHYSICAL CHANGES	_____ 40. DIFFUSION OF LIQUIDS
_____ 3. CHEMICAL CHANGES	_____ 41. ABSORPTION BY CELLS
_____ 4. REVERSING A CHEMICAL CHANGE	_____ 42. ROOT HAIRS
_____ 5. ACIDITY AND ALKALINITY	_____ 43. FLESHY ROOTS
_____ 6. CHANGE OF HEAT INTO MOTION	_____ 44. ROOT PRESSURE
_____ 7. COMPOSITION OF MILK	_____ 45. TYPES OF ROOTS
_____ 8. DECOMPOSITION OF WATER	_____ 46. AIR AND STARCH-MAKING
_____ 9. RELATION OF AIR TO FIRE	_____ 47. LIGHT AND STARCH-MAKING
_____ 10. REACTION OF FIRE UPON AIR	_____ 48. CHLOROPHYL AND STARCH-MAKING
_____ 11. PART OF AIR USED UP IN FIRE	_____ 49. PLAN FOR AN EXPERIMENT
_____ 12. EFFECT OF CO ₂ ON LIMEWATER	_____ 50. GAS EXCHANGE IN STARCH-MAKING
_____ 13. PARTS OF AIR RELATED TO FIRE	_____ 51. LEAF AS A FACTORY
_____ 14. INORGANIC GROWTH	_____ 52. WHAT IS AN EXPERIMENT?
_____ 15. GROWTH OF A CRYSTAL	_____ 53. TRANSPIRATION
_____ 16. FUNCTIONS OF ORGANS	_____ 54. STRUCTURE OF LEAF
_____ 17. THE MICROSCOPE	_____ 55. TRANSPIRATION PULL
_____ 18. USE OF THE MICROSCOPE	_____ 56. CHEMICAL CHANGES IN DIGESTION
_____ 19. PLANT CELLS	_____ 57. PHYSICAL CHANGES IN STARCH-DIGESTION
_____ 20. ANIMAL CELLS	_____ 58. DIGESTION OF PROTEINS
_____ 21. THE ENVIRONMENT OF SEEDS	_____ 59. DIGESTION IN MAN
_____ 22. WATER AND SPROUTING	_____ 60. THE TEETH
_____ 23. AIR AND SPROUTING	_____ 61. FOOD VALUES
_____ 24. GASES OF AIR AND SPROUTING	_____ 62. FOOD ECONOMY
_____ 25. PLAN FOR AN EXPERIMENT	_____ 63. BREATHING IN INSECTS
_____ 26. EFFECTS OF SPROUTING ON AIR	_____ 64. BREATHING IN FROG
_____ 27. SPROUTING AND TEMPERATURE	_____ 65. BREATHING IN FISH
_____ 28. SOIL ELEMENTS AND GROWTH	_____ 66. COMPARATIVE STUDY OF BREATHING
_____ 29. EMBRYO OF THE SEED	_____ 67. EXERCISE AND BREATHING
_____ 30. STRUCTURE OF A GRAIN	_____ 68. EVAPORATION AND TEMPERATURE
_____ 31. SEEDLINGS BREAKING GROUND	_____ 69. EVAPORATION AND MOISTURE
_____ 32. COTYLEDONS AND GROWTH OF SEEDLINGS	_____ 70. DUSTY TRADES
_____ 33. TEST FOR STARCH	_____ 71. STRUCTURE OF STEMS
_____ 34. TEST FOR PROTEINS	_____ 72. MONOCOT AND DICOT PLANTS
_____ 35. OIL IN SEEDS	_____ 73. FOOD DUCTS IN BARK
_____ 36. GRAVITY AND ROOTS	_____ 74. CAPILLARITY
_____ 37. REGION OF GREATEST GROWTH	_____ 75. STRUCTURES OF THE BLOOD
_____ 38. LIGHT AND GROWTH OF PLANTS	_____ 76. CLOTTING OF BLOOD

LIST OF EXERCISES (*Continued*)

EXERCISE

- _____ 77. BLOOD AND GAS EXCHANGE
- _____ 78. CHANGES IN COMPOSITION OF BLOOD
- _____ 79. EXERCISE AND THE PULSE
- _____ 80. EXCRETION
- _____ 81. EXCRETION IN ROOTS
- _____ 82. THE KIDNEY
- _____ 83. THE SKIN
- _____ 84. TYPES OF EXCRETORY ORGANS
- _____ 85. PLAN FOR AN EXPERIMENT
- _____ 86. CONTROL OF THE REFLEXES
- _____ 87. BRAINLESS ACTS
- _____ 88. THE SENSE OF TOUCH
- _____ 89. FEELING HOT AND COLD
- _____ 90. THE SENSE OF TASTE
- _____ 91. DETECTING FLAVORS
- _____ 92. NEAR SIGHT AND FAR SIGHT
- _____ 93. FEELING LIGHT WITHOUT EYES
- _____ 94. THE EARS
- _____ 95. ACUTENESS OF HEARING
- _____ 96. KEEPING A BALANCE
- _____ 97. INHIBITION
- _____ 98. COMMON LIFE PROCESSES
- _____ 99. NUTRITION OF CELL AND OF ORGANISM
- _____ 100. RESPIRATION OF CELL AND OF ORGANISM
- _____ 101. EXCRETION OF CELL AND OF ORGANISM
- _____ 102. COMPARATIVE STUDY OF NUTRITION
- _____ 103. COMPARATIVE STUDY OF RESPIRATION
- _____ 104. COMPARATIVE STUDY OF EXCRETION
- _____ 105. LOCOMOTION : ANALOGIES AND HOMOLOGIES
- _____ 106. REACTIONS TO DISTURBANCE
- _____ 107. FOOD-GETTING AND EATING
- _____ 108. RELATION OF VOLUME AND AREA
- _____ 109. REGENERATION
- _____ 110. SEGMENTATION
- _____ 111. MOSQUITO, LIFE HISTORY

EXERCISE

- _____ 112. TEMPERATURE AND DEVELOPMENT
- _____ 113. SPORE DISTRIBUTION
- _____ 114. SPIROGYRA CONJUGATION
- _____ 115. GERMINATION OF SPORES
- _____ 116. THE FLOWER
- _____ 117. FLOWER STUDIES
- _____ 118. THE POLLEN TUBE
- _____ 119. WIND POLLENATION
- _____ 120. INSECT POLLENATION
- _____ 121. THE FRUIT
- _____ 122. DISTRIBUTION OF SEED
- _____ 123. LIFE HISTORY OF MOSS
- _____ 124. LIFE HISTORY OF FERN
- _____ 125. SPOROPHYTE AND GAMETOPHYTE
- _____ 126. ALTERNATION OF GENERATIONS
- _____ 127. PARENTAL CARE
- _____ 128. RELATION OF LIGHT TO GROWTH
- _____ 129. SEASONAL CHANGES
- _____ 130. STRUGGLE AND SURVIVAL
- _____ 131. CHANGES IN PIGMENTATION
- _____ 132. PROTECTIVE MOVEMENTS
- _____ 133. HOMOLOGY : PROTECTIVE ORGANS
- _____ 134. PROTECTIVE ACTIVITIES
- _____ 135. FALL OF LEAVES
- _____ 136. THE FOREST FLOOR
- _____ 137. MOUTH WASHES
- _____ 138. ECONOMIC MICROORGANISMS
- _____ 139. FLIES AS DISTRIBUTORS OF GERMS
- _____ 140. FLY SURVEY
- _____ 141. MOSQUITO SURVEY
- _____ 142. ECONOMIC INSECTS
- _____ 143. BIRDS
- _____ 144. VARIATION
- _____ 145. RATIO OF DOMINANTS AND RECESSIVES
IN HYBRIDS

EXERCISES IN ELEMENTARY BIOLOGY

EXERCISE 1

Our world is made up of things that are constantly changing. Both living and non-living things change from day to day, from season to season.

Problem. What are some of the changes occurring in the world about us?

What to use and what to do. Using the following blanks, in each column describe five changes (in addition to the example printed) that happen to the kind of things named at the head of the column.

WEATHER	PLANTS	HUMAN BEINGS AND OTHER ANIMALS	NON-LIVING OBJECTS
<i>The air becomes warmer between sunrise and noon</i>	<i>Buds on a tree open</i>	<i>A sick person gets well</i>	<i>The water on a pond changes from liquid to solid</i>
1.			
2.			
3.			
4.			
5.			

Questions to think about. 1. What kinds of changes in the world do you find most interesting?

2. What kinds of changes in the world would you consider most important?

NOTE. In some of the changes (for example, melting ice or dissolving sugar) the matter takes on new appearances or qualities, but the substance remains the same. Such a change is called a *physical change*. In other changes, certain of the substances in the object seem to disappear entirely and new materials to make their appearance, as in a flame or in frying eggs. Changes of this kind are *chemical changes*.

EXERCISE 2

Problem. What happens in some common physical changes (for example, pulverizing, dissolving, melting, evaporating) ?

What to use. 1. Any substance that you know you can pulverize ; any that you know you can dissolve ; any that you know you can melt ; any that you know you can evaporate.

2. Any additional things, material, etc. that you need in order to bring these changes about.

What to do. 1. Pulverize a substance.

2. Dissolve a substance.

3. Melt a substance.

4. Evaporate a substance.

Record. Make entries in proper spaces of this table.

	PULVERIZE	DISSOLVE	MELT	EVAPORATE
<i>What material was used?</i>				
<i>What was done to produce result?</i>				
<i>How does the stuff after change differ from its condition before change?</i>				

Question to think about. In what way are all these *changes* alike?

EXERCISE 3

When a substance is acted upon in such a way that the particles of which it is made are completely rearranged, a chemical change is produced. We cannot always recognize a chemical change at once, but certain appearances usually indicate such a change. Any one substance may undergo many different chemical changes, just as any one substance or object may undergo many physical changes.

Problem. To show some of the different chemical changes that a single substance may undergo.

What to use. Sodium carbonate (washing soda) solution; water; hydrochloric acid (dilute 10%); barium chlorid; phenolphthalein; 5 test tubes and rack; 1 beaker.

What to do. Have about 1 inch of the solution indicated in the different tubes. Pour solution from the beaker into the test tubes, drop by drop. Note what happens immediately after the addition of sodium carbonate to the solution in each tube. After a few minutes shake the contents of each tube gently and note results.

Record. Describe the results of adding sodium carbonate to *each* tube.

Questions. Which of the changes you have described would you consider physical and which chemical? Why?

NOTE 1. The alteration that is brought about by the action of one thing or substance upon another is called the reaction.

NOTE 2. The discharge of bubbles of gas from a solution is called effervescence.

NOTE 3. The production of solid particles in a solution is called precipitation, which means "throwing down."

EXERCISE 4

Just as we can reverse the change from ice to liquid water or from fluid to solid water, we can reverse a chemical change in some cases, but not in all. A boiled egg cannot be made raw again; a piece of charcoal cannot be worked up into wood; dried oil paint cannot be turned back into fresh paint.

Problem. How may I show a reversible chemical reaction?

What to use. The colored phenolphthalein solution of the last experiment; 10 per cent hydrochloric acid; the beaker of washing soda; some litmus solution or litmus paper; test tubes; rack.

What to do. Add hydrochloric acid, drop by drop, to colored phenolphthalein solution, counting the drops carefully. Shake tube gently after the addition of each drop. Note when color disappears. Then add, drop by drop, counting each drop, sodium carbonate; again, hydrochloric acid; again, sodium carbonate.

Record. Tell what happens when the measured amount (that is, number of drops counted) of the substance used in the experiment has been added to the solution in the test tube.

NOTE 1. The hydrochloric-*acid*, or sour, solution and the carbonate, or *alkaline*, solution counteract or neutralize one another. A given amount of acid substance will neutralize a certain quantity of alkaline substance, and vice versa. The quantity of a *solution* required to neutralize another depends upon the relative *concentration* of acid and alkali.

NOTE 2. Phenolphthalein is colorless in a *neutral* or *acid* solution, but it turns red in an *alkaline* solution. Substances that react differently in two kinds of solution may thus be used as "indicators."

NOTE 3. Litmus solution, made from a vegetable dye, or litmus paper, which is made by saturating paper with the dye, is a common indicator used in chemical and biological laboratories.

Repeat the above experiment, using litmus solution or litmus paper in place of phenolphthalein.

Record results.

EXERCISE 5

Using small pieces of litmus paper, test many different articles at home and fill out following table :

NAMES OF SUBSTANCES THAT ACTED ON LITMUS PAPER JUST AS DID THE ACID IN THE PREVIOUS EXPERIMENT :	NAMES OF SUBSTANCES THAT ACTED ON LITMUS PAPER AS DID THE SODIUM CARBONATE :
ACID SUBSTANCES	ALKALINE SUBSTANCES

Questions. What use might be made of an acid-alkali indicator by (a) a doctor? (b) a nurse? (c) a housekeeper?

EXERCISE 6

Whenever a change takes place, there is not only a rearrangement of matter, but there is also a change in what we call "energy." For example, when two solids (matter) are moved against each other, their motion (energy) is changed into *heat* (energy); when two solids (matter) are struck against each other, their motion (energy) is changed into sound waves (energy).

Problem. Can heat be changed to motion?

What to use. A flask of colored water, closed with a one-holed rubber stopper; a long piece of glass tubing connected as shown in diagram; a source of heat.

What to do. Apply heat and note its effect upon the water.

Record. Describe changes that take place:

WHAT WAS DONE	HOW MATTER CHANGED	ENERGY CHANGES

Questions. 1. Is there really more liquid or less liquid than there was before heating?

2. What do you suppose happened to the liquid to make it *seem* of a different quantity?

Home exercise. Make a list of six ordinary events or actions and tell what change or changes took place in the matter and what changes took place in the energy.

	HAPPENING	HOW MATTER CHANGED	ENERGY CHANGE
Example	<i>Breathing out against vocal cords</i>	<i>Cords vibrate and emit sound</i>	<i>Muscular contractions changed into sound</i>
1			
2			
3			
4			
5			
6			

EXERCISE 7

Some of the substances with which we are acquainted seem to be exactly the same in all parts — for example, glass, water, iron. Others we can see are made up of different kinds of particles — for example, streaks in marble, wood, ink.

Problem. What are some of the parts that make up milk?

What to use. For the entire class, quart bottle of milk; pipette; evaporating dish; water bath; crucible; support; flame. For each pupil, two test tubes and rack; funnel; piece of filter paper; acetic acid.

What to do. Allow the milk to stand overnight, and remove the cream by pouring off or by the use of a pipette. The residual milk (skimmed) is then distributed to members of class, each taking about two tablespoonfuls, or milk enough to fill test tube one third full. Now add acetic acid to the milk, drop by drop, until a precipitate is formed. Separate the solid substance (curd) from the liquid whey by pouring into a filter paper supported by a funnel.

NOTE 1. The curd is made up largely of a substance called casein. This is held in solution by the alkali naturally present in the milk. In an acid solution casein precipitates out as curd.

The teacher will collect all the whey and evaporate to dryness over a water bath or in a double boiler.

When all water has been driven off, assemble the solid material (it consists of sugar, milk albumen, and other substances) in a crucible and treat the material with a flame until nothing is left that will burn.

NOTE 2. The part remaining after burning is called ash or, sometimes, mineral matter.

Record. Make an outline of the substances that make up milk. Opposite each item tell how each is separated from other constituents.

- Questions.** 1. Why does a housekeeper add baking soda to milk when it begins to turn?
2. Could milk be used to demonstrate reversible chemical action?

EXERCISE 8

Although water seems to be a simple substance, it has been found to be made up of still simpler substances.

Problem. How can we show that water is made up of simpler substances?

What to use. Have the teacher borrow a eudiometer, or make one as shown in the diagram. A direct current from a general circuit, from a storage battery, or from four dry cells; water; sulfuric acid; matches; splints.

What to do. Set up the eudiometer or the piece of apparatus shown. Over the ends of the wires have two inverted tubes full of water containing a *small* amount of acid.¹ Turn on the current or complete the circuit until one tube is full of gas.

Note the changes that take place in each tube. Remove and invert each tube and treat with a burning match, then with a glowing splint.

Record. Describe what happened after closing the circuit. If dry cells are used, decide whether more gas is given off at the carbon (+) or at the zinc (−) pole of the battery. If a storage battery is used, note whether more is given off at the + or at the − pole.

Questions. 1. In what ways are the two gases alike?

2. (a) Which gas burns? (b) What is formed by the burning?

3. How can you recognize the other gas?

NOTE 1. Water is broken down into two parts. The one of which the volume is larger is called hydrogen. The other is called oxygen.

NOTE 2. Water, up to the present time, has never been divided into simpler parts than oxygen and hydrogen. We cannot break up oxygen into anything simpler than oxygen, nor hydrogen into anything simpler than hydrogen. A substance such as oxygen or hydrogen, gold, silver, chlorine, which we have not been able to break up into simpler kinds of matter, is called an *element*. A chemical combination of two or more elements is called a *compound*.

¹ Pure water will not conduct the electric current; but with acids or some other substances dissolved in it, water is a conductor of electricity.

EXERCISE 8 (Continued)

4. What are some of the compounds you have studied so far?

NOTE 3. By burning some hydrogen in air we can easily show that hydrogen combines with oxygen to form water. Pour dilute hydrochloric acid into a flask containing some small pieces of zinc covered with water. *After all the air is out of the flask* bring a lighted match to the nozzle, and then hold a clean, *dry* bottle or test tube over the flame.

CAUTION. If a flame is brought near the gas outlet while there is still air in the apparatus, there is danger of a serious explosion.

5. What proportions do you suppose you would have to use if you were to combine volumes of hydrogen and oxygen for producing water?

6. The chemist uses a shorthand way of writing water: $\frac{\text{H}}{\text{H}} > \text{O}$, or H_2O . Give whatever reasons you can think of for the use of either or both of these methods of representing water.

EXERCISE 9

In order to understand living things we ought to know a great deal about burning. We all know that air has something to do with burning.

Problem. How is air related to fire?

What to use. Lighted candle for fire; jar; glass plate.

What to do. After making certain that the candle will burn in air, cut off the supply of air by inverting the jar over the lighted candle.

Record. Tell in detail what you saw happen to the candle and to the jar.

Conclusion. What do the results show about the relation between air and fire?

Questions. 1. How can you tell that it was not the glass of the jar that produced the result?
2. How can you tell that the flame was not poisoned by gases given off by the fire?

EXERCISE 10

Problem. Does fire use up some part of the air or does it produce new gases?

What to use. A tall cylinder to inclose air; a basin of water to act as a seal for the air; cork float holding candle on water.

What to do. Light candle, float on water, invert jar and carefully place over candle and float.

Record. Note all the changes that take place.

- Questions.**
1. Is the same proportion of the air used up in every fire?
 2. Is the remaining air different from fresh air?
 3. From what happened, can you tell just what part the air took in the burning?

EXERCISE 11

Problem. What becomes of the substance taken from the air when something burns?

What to use. Piece of magnesium ribbon 8 inches long; scales; weights; funnel; match; cotton plug.

What to do. Carefully balance the funnel which incloses the magnesium ribbon. Support the magnesium on a cork, and bend it so that it does not touch at any point. Ignite the free end; be careful not to lose any of the ashes.

Record. Tell all the changes that take place.

- Questions.**
1. Is total weight of smoke and ash greater or less than that of original "fuel"?
 2. How do you account for the difference?
 3. How does the ash or smoke differ from the original magnesium?
 4. What is the composition of the white powder?

EXERCISE 12

In Exercise 2 we learned that there are certain substances (phenolphthalein and litmus were examples given) called indicators for acids and alkalies; we use such an indicator to test, or try out, the acidity or alkalinity of a substance. In the study of living things we often need an indicator to test the presence of some particular substance, and different indicators are accordingly used.

In Exercise 3 we also learned that a given substance may react in a distinct way with other substances; for example, sodium carbonate (washing soda) and barium chlorid together produce a white precipitate. But we do not know whether sodium carbonate can produce a precipitate with substances other than barium chlorid; nor do we know whether barium chlorid can produce a precipitate with something else besides sodium carbonate.

Problem. To find the effect of carbon dioxide on limewater.

What to use. Gas generator (see figure); limewater with container.

What to do. Prepare some carbon dioxide gas by means of apparatus such as shown in diagram; pour dilute hydrochloric acid on marble chips through the thistle tube. Allow the gas to bubble through the limewater.

Record. Note the changes that take place in the limewater.

NOTE 1. Chemists have made thousands of experiments to learn the effects of various gases on limewater, and similar ones to learn the effects of carbon dioxide upon various substances. Whereas carbon dioxide will produce a white precipitate with various solutions, it is the *only* gas that will produce a precipitate in limewater. We may therefore be sure of the presence of this gas when we see limewater turn turbid, or milky.

Question. Write out a method for determining the presence or absence of carbon dioxide gas in the breath; test for the presence or absence of carbon dioxide gas in illuminating gas.

NOTE 2. Just as we used the symbol H_2O , or $\begin{smallmatrix} \text{H} \\ \text{H} \end{smallmatrix} > \text{O}$, to represent water, we denote carbon dioxide by the shorthand method of CO_2 , or $\text{C} < \begin{smallmatrix} \text{O} \\ \text{O} \end{smallmatrix}$.

EXERCISE 13

Ordinary air is a *mixture* of gases made up approximately of the following :

Nitrogen	about 79%, or $\frac{4}{5}$ of volume
Oxygen	about 20%, or $\frac{1}{5}$ of volume
Carbon dioxid	about $\frac{1}{25}\%$

Problem. What is the relation of each of the principal gases found in air to burning ?

What to use. Wide-mouthed bottles for containing gases ; glass covers ; splints ; matches ; nitrogen ; oxygen ; carbon dioxid ; water.

The nitrogen will be prepared by the teacher or a committee of students and supplied as needed.

To prepare carbon dioxid, see Exercise 12.

To prepare oxygen, place a small piece of sodium peroxid¹ (sold under the trade name "Oxone") under the mouth of an inverted bottle full of water, or heat a mixture of one part manganese dioxid and three parts potassium chlorate in a large tube connected with the gas collector.

What to do. Plunge a lighted splint into a bottle of air, noting the results. Do the same with a bottle of nitrogen ; a bottle of

carbon dioxid ; a bottle of oxygen. Repeat in each case until you are sure of the results. Repeat with a glowing splint.

Record. Describe completely what happened in each case. Answer the question in Problem as concisely as you can.

Questions. 1. What would be the result of a great change in the proportion of the gases in our atmosphere ?

2. How does blowing into a flame make it burn more briskly ?

3. What can be done to intensify combustion besides increasing the air supply ?

¹ It is not safe to use pulverized peroxid.

EXERCISE 14

Growth is believed by many people to be peculiar to living things, but a very similar process is sometimes found among non-living things.

Problem. To show in non-living things a process that resembles growth in living things.

What to use. A vessel (beaker or jar) with cover; clean sand; numbers of different kinds of crystals, such as zinc sulfate, ferrous sulfate, copper sulfate, chrome alum, etc.; sodium silicate (water glass), 1 part to 10 parts water.

What to do. Place a thin layer of sand on bottom of beaker. Place on the sand a few crystals of various sizes; pour in diluted water glass to a height of two or three inches; cover. Put in a safe place and do not disturb for six or seven days.

Record. Note any changes that take place in the jar.

- Questions.** 1. In what ways does the behavior of the things in the jar resemble that of living things?
2. In what ways does it differ from that of living things?

EXERCISE 15

Problem. To show growth of crystals.

What to use. Water ; tumbler or beaker ; rod ; thread. Select one of several substances, such as sugar, alum, hypo salt, table salt, copper sulfate, etc.

What to do. Stir into half a glass of warm water a little more of your chemical substance than can be completely dissolved. Weight a thread with a crystal of the substance used in the experiment, and suspend in the solution ; leave undisturbed for a few days.

Record. Note what happens. If crystals are formed on the thread, dry, bring to school, and place in school museum.

- Questions.**
1. In what ways does the growth of a crystal differ from the growth of a baby ?
 2. In what ways does the growth of a crystal differ from the growth of a plant ?
 3. What other things grow in the same way as a crystal ?

EXERCISE 16

The work which any organ performs or the way it behaves in relation to the plant or animal of which it is a part is called its functions. Some organs perform no functions useful to the organism. Human beings make *use* of various parts of plants and animals. This use may or may not have anything to do with the function of the part.

In the following tables indicate the *uses* to which we can put the ten named organs of certain animals or plants and the *functions* of these organs in the life of the organism.

	ANIMAL ORGANISM	PART CONSIDERED	HOW USED BY MAN	FUNCTION IN ORGANISM
Example	<i>Ox</i>	<i>Tongue</i>	<i>Food</i>	<i>Grasps his food</i>
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

	PLANT ORGANISM	PART CONSIDERED	HOW USED BY MAN	FUNCTION IN ORGANISM
Example	<i>Hemlock</i>	<i>Bark</i>	<i>Tanning material</i>	<i>Protects growing layer</i>
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

EXERCISE 17

The compound microscope is a very delicate instrument, embodying a great deal of scientific knowledge and mechanical skill. It should be handled with intelligence and consideration.

Problem. What are the parts of the microscope, and how should it be used?

What to use. A compound microscope; a prepared slide.

What to do. 1. Study the microscope as you read the description of its structure below.

2. Study the specimen on the prepared slide, following the directions carefully.

Record. 1. On the left-hand side, label all the parts of the microscope picture with the names that are underlined in the description. On the right-hand side, tell the use, or function, of each part that has been labeled.

2. Make a drawing of the object studied under the low power of the microscope, as large as it appears.

NOTE. 1. There are three distinct sets of parts in a compound microscope: (a) the *mechanical*, which support the other parts and make possible their controlled movements; (b) the *optical*, which actually do the magnifying by their effect upon the rays of light passing through them; and (c) the *illuminating*, which direct and regulate the light supply.

2. All of the mechanical parts together constitute the stand, which has a heavy base, supporting a leg, or pillar. Projecting horizontally from the top of the pillar, parallel with the base, is the flat stage, with a hole in the middle for letting light through. Above the stage is a continuation of the pillar, and extending from this over the stage is the arm, which carries a vertical tube. Projecting on both sides of the arm are knobs with rough edges. These are connected with a pinion that makes the tube go up or down when they are turned. The knobs, with the rack and pinion, make up the "coarse adjustment," and the knobs are sometimes called the coarse adjustment or coarse-adjustment screws. By turning them gently (one at a time) you can see the effect on the tube. The coarse adjustment is used to change the distance between the lenses and the object to be observed; that is, to focus. At the very top of the pillar is another screw, the fine adjustment, which is also used for focusing but is much more delicate than the coarse adjustment.

3. The optical system consists of two sets of lenses in metal cases. The set placed at the lower end of the tube, near the object, is called the objective. On some microscopes there is a special attachment at the base of the tube for carrying two or more objectives conveniently; this is the nosepiece. With the use of the nosepiece it is possible to change from one objective to another with no loss of time. The objective that is in line with the tube would be the one in use. Where there are two or more objectives, the longer or longest is of greater magnifying power. At the other end of the tube, near the eye, is a set of lenses in a metal case, called the eyepiece, or ocular. This is easily taken out of the tube.

4. The illuminating system consists of the mirror, hung under the stage, and of the diaphragm, inserted in the opening of the stage. The mirror usually has two faces, one flat and one concave. It can be turned in all directions and is used for throwing a beam of light from the window (or a suitable lamp) up through the object resting on the stage, through the objective and through the ocular, into the eye. The diaphragm is an arrangement for enlarging or diminishing the amount of light coming through, by making the opening larger or smaller.

5. Some microscopes have a joint in the pillar, just below the stage, permitting the upper part of the stand to be tilted into a more convenient position. On some microscopes one or two clips on the upper surface of the stage hold the slide in place.

CAUTION. In lifting or carrying the microscope, grasp it firmly around *the pillar under the stage*, unless there is a special handle for grasping above the stage.

Allow nothing to touch any of the optical parts except specially prepared lens paper or a clean linen handkerchief.

Questions. 1. In which direction must the coarse adjustment be turned to raise the tube?

2. In which direction must the fine adjustment be turned to raise the tube?

Using the coarse adjustment, raise or lower the tube until the tip of the low-power objective is about half an inch above the stage.

Looking through the eyepiece, turn the mirror until you have an even white field of light.

EXERCISE 17 (Continued)

CAUTION. From the very first use of the microscope *keep both eyes open*. If you attend to what you see inside the microscope, what the other eye sees will not disturb you. Keeping both eyes open avoids straining the eyes.

Place the prepared slide on the stage, with the object as near the center of the hole in the diaphragm as possible.

Look through the eyepiece and gently raise the tube, with the coarse adjustment, until you see a clear image. By turning gently back and forth with the fine adjustment you may get a sharper focus.

After the object is in focus you may try to improve the illumination by gently moving the mirror back and forth in various directions and by trying smaller and larger openings of the diaphragm.

After making the drawing get a view through the high power as follows: while the object is sharply in focus turn the nosepiece carefully to bring the other objective in line with the tube; listen or feel for the click which indicates that the objective is centered. Then look through the eyepiece and gently adjust with the fine adjustment.

CAUTION. Always begin focusing *upward*, and guard against bringing the objective in contact with the cover glass.

Questions. 1. Why is more light needed for study with the high power than for study with the low power?

2. Who invented the microscope?

EXERCISE 18

Problem. What does looking through the microscope do to the appearance of an object?

What to use. Compound microscope ; slide ; cover slip ; piece of printed paper with very small type.

What to do. Place a drop of water on the slide ; immerse paper in the water ; place cover slip over paper, focus under low-power objective. Keep both eyes open ; draw what you see. Center dot of an "i" in the field, using the low power ; then turn to high power ; focus carefully ; draw.

Record. Make an outline drawing exactly the size seen. In order to help you properly to gauge the size of the letter, place a ruler on the table alongside of the base of the microscope. Try to focus and examine the letter *with both eyes open*. Keep comparing the size of the field and the dot or letter with the ruler. After the drawing is made, make a scale by measuring off the length of the letter used on the slide. Note how many times the letter seems to have been enlarged when viewed through low power ; through high power. Find out what the power of the two lenses is supposed to be after your calculation is finished and recorded.

Special exercise. Look up the history of the microscope and report in class.

Questions. 1. What happens to the image when the object (slide) is moved to the right?

2. What does the lens system do to the appearance of the object (image) besides enlarging it?

3. What are some important uses of the microscope?

4. What important social or economic changes have resulted from perfection of the microscope?

EXERCISE 19

Problem. What do plant cells look like when examined through a microscope?

What to use. Compound microscope; slide; cover slip; water; onion; elodea or nitella; iodine solution or methyl blue.

What to do. First remove the outer portion of the onion, then carefully peel a bit of the skin from the soft, fresh part. Drop into a flat dish containing tincture of iodine or methyl blue. Place flat in a drop of water on a slide; cover with cover glass. Examine under low power and under high magnification.

Next mount a small leaf of elodea or nitella (green water plants used in aquaria). Warm by holding slide on hand and blowing breath upon it. Examine under low and under high magnification.

Record. Make careful outline drawings of several cells of the onion preparation and of the green plant cells.

Note the cell wall which incloses the living fluid, called protoplasm. Part of this living fluid (the nucleus) absorbs dyes and becomes stained. In green plant cells tiny green bodies called plastids float in the streaming protoplasm. These green plastids are called chloroplasts. Identify all the above structures and label the drawings.

Questions. 1. By slowly moving screw of fine adjustment (see Exercise 17) can you prove that a cell has a third dimension, that is, thickness as well as length and width?

2. What causes the green color of leaves? Can you tell what causes the colors of flowers?

3. What is your definition of a plant cell?

4. Look in the encyclopedia and write a paragraph on (a) Robert Hooke; (b) Schleiden and Schwann; (c) the cell theory. ✓

EXERCISE 20

Problem. What do animal cells look like when viewed through the microscope?

What to use. Microscope; slides; cover slips; prepared slides of various tissues, scraping from lining of mouth, gills from clam, or drop of water from hay infusion.

What to do. Examine several different animal cells, preparing as in previous exercise.

Record. Make careful drawings of several different kinds of animal cells; label parts of cell that were noted in the plant cell.

Questions. 1. In what ways may cells differ from each other?

2. In what ways do the animal cells studied differ from the plant cells?

3. Why, do you suppose, were plant cells discovered nearly two hundred years before animal cells?

EXERCISE 21

Problem. Why is it that seeds placed under certain conditions will germinate or sprout, whereas under other conditions they remain unchanged?

What to do. Make a list of all the things, substances, or conditions in the environment (surroundings) that in your judgment *have something to do* with sprouting. For example, you may think that the fence around a field or the color of the flowerpot has (or has not) some relation to the sprouting; you may think that the darkness inside a bin or the light coming through a glass jar containing seeds is an important factor.

All the factors in the environment which *may* influence germination :

1.	6.
2.	7.
3.	8.
4.	9.
5.	10.

In the light of all that you *know* about the sprouting of seeds, place a + after each item that you are sure is a necessary factor in germination; place a 0 after every item that you know is *not* necessary; and place a ? after each item in regard to which you are in doubt.

Questions. 1. How do you know that the first item you have marked + is essential to the sprouting of seeds?

2. How do you know that the first item you have marked 0 is not essential?

3. Is your doubt in regard to any item marked ? due to your lack of experience or to conflicting observations?

4. What factors of importance had you overlooked that other students reported?

EXERCISE 22

Problem. What is the relation between water and the sprouting of seeds?

What to use. Any large seeds (bean, pea, maize); several vessels of the same kind (bottles, tin cans, cups); water.

What to do. Arrange a series of five vessels, each vessel containing a *different* quantity of water; use seeds of the *same* kind. Such a series may be made by supplying equal numbers of seeds (ten or a dozen) with varying quantities of water—for example, no water at all; one thimbleful or teaspoonful; two; four; etc. The seeds in the last vessel of the series should be placed in water an inch or more deep. Set all together in a safe place.

Record. At intervals of about twenty-four hours record the condition of the seeds in words or picture.

VESSEL OR BOTTLE	NUMBER AND KINDS OF SEEDS	QUANTITY OF WATER	OBSERVATIONS						
			First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Seventh Day
<i>A</i>									
<i>B</i>									
<i>C</i>									
<i>D</i>									
<i>E</i>									

Conclusion. What do the results show as to the relation between water and sprouting?

Questions. 1. How can you tell that it was not the *air* that made some seeds sprout faster than others?

2. How can you tell that it was not the *temperature* that made some seeds sprout faster than others?

3. How can you tell that it was not the *light* that made some seeds sprout faster than others?

4. Plan an experiment that would answer this question.

5. How can you tell that the sprouting was not merely the soaking up of water?

EXERCISE 23

Problem. Has air anything to do with the sprouting of seeds?

What to use. Seeds that have been soaked overnight (pea, bean, or maize); vessels that can be sealed air tight; sand.

What to do. Place groups of seeds ready to sprout in situations having *varying quantities* of air. This can be done by using vessels of the same size and equal numbers of seeds, displacing air by means of sand (as shown on left side of diagram), or by using same-sized bottles and varying number of seeds. Have experiment tried in different ways by parts of the class.

Place all bottles in same place; make observations twenty-four hours apart.

Record carefully all changes by words or pictures.

	NUMBER OF SEEDS	QUANTITY OF AIR	OBSERVATIONS					
			First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day

Conclusion. What has the amount of air to do with sprouting?

Question. How can you tell that the differences in result were not due to factors other than air?

EXERCISE 24

From a previous experiment (Exercise 23) we learned that air is one of the factors necessary for germination. We might well ask ourselves the same questions concerning sprouting of seeds as we did concerning the flame. Reviewing the make-up of air, consider the following:

Problem. What part (or parts) of the air is related to sprouting?

What to use. Bottles of no air, if an exhaust pump is available; of oxygen; of nitrogen; of carbon dioxide; soaked seeds (peas, beans, or maize); air.

What to do. Place equal numbers of seeds in bottles containing the above gases. Have one bottle containing air as a control, or check.

Record. Make careful observation of results twenty-four hours apart.

CONTENTS OF CONTAINERS	OBSERVATIONS						
	First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Seventh Day
<i>Air + seeds</i>
<i>No air + seeds</i>
<i>Nitrogen + seeds</i>
<i>Oxygen + seeds</i>
<i>CO₂ + seeds</i>

Conclusions. From the results what can you tell about the relation of nitrogen, oxygen, etc. to sprouting?

EXERCISE 25

Work out a plan for determining whether *variations* of *temperature* influence the sprouting of seeds.

Draw up your Problem.

Tell what you would *use*.

Tell what you would *do*.

Tell what *results* might be expected.

Tell what *conclusions* you would draw from *each* set of results.

Question. What practical use could be made of the information?

EXERCISE 26

Problem. Does the sprouting of seeds produce any change in the surrounding air?

What to use. Two flasks or bottles; seeds; corks; vials containing limewater; wire; splints; matches.

What to do. Place soaked seeds in each bottle; to one add a few drops of formalin to kill the seeds; carefully suspend a vial of limewater in each with a wire; cork; seal.

Record. After twenty-four hours note what happens to the limewater; shake gently and observe again. Test both bottles for oxygen. What happened to the lighted splints? to the spark?

Conclusions. What gas is increased in quantity when seeds sprout? What gas is diminished in quantity?

Questions. 1. What is the probable relation between the changes in the air and changes inside the seed?

2. Why were two bottles used in this experiment?

EXERCISE 27

There are many different chemical processes going on in plants and animals. Oxidation is not the only one, but it seems to be nearly universal, and it makes available to living matter the energy for its various activities.

Problem. Is heat energy released when seeds sprout?

What to use. Three containers; large seeds, some soaked, some dry; three thermometers.

What to do. Hang up thermometers and note whether they agree as to temperature recorded. Fill three bottles, one with dry seeds, one with soaked seeds, one with seeds that have been soaked in water to which a few drops of formalin have been added.

Record. Note the reading of the thermometers at twenty-four-hour intervals.

	CONDITION OF SEEDS	READING OF THERMOMETERS						
		First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Seventh Day

Conclusions. What is there in the results that enables us to answer the question in the Problem?

Questions. 1. Under what conditions do the seeds change the temperature most?

2. What is the effect of the formalin in this experiment?

3. How can you tell whether changes in temperature during sprouting are related to oxidation?

EXERCISE 28

Eight or nine elements are present in the most common salts found in soil. These elements are found combined, two or three being present in most of the salts. Thus, sodium chlorid (common salt) contains sodium and chlorine; potassium nitrate contains potassium, nitrogen, and oxygen; and so on. We saw that seeds can *sprout* without depending upon soil; yet something in the soil is essential to the *growth* of plants.

Problem. Which of the substances in the soil are necessary for the continued growth of plants?

What to use. Young plants grown from seeds, with roots carefully washed in water; eight wide-mouthed bottles with corks; distilled water; chemicals required for a nutritive solution (p. 24 of Teachers' Manual).

What to do. Prepare a nutrient solution containing all the salts given in the formula. Prepare another solution from which one of the salts is omitted; one from which the second salt is omitted; and so on. Observe growth and other changes from day to day.

Record. Enter the results in the proper spaces of the table on the next page.

Questions. 1. Which salt or salts would seem to affect *growth*?

2. What other changes are brought about by the absence or presence of particular substances?

EXERCISE 28 (Continued)

BOTTLE NUMBER	GROWING-MEDIUM	FIRST DAY	SECOND DAY	THIRD DAY	FOURTH DAY	FIFTH DAY
1	<i>Distilled water</i>					
2	<i>Containing all nutrients</i>					
3	<i>Lacking potassium nitrate</i>					
4	<i>Lacking calcium sulfate</i>					
5	<i>Lacking calcium phosphate</i>					
6	<i>Lacking magnesium sulfate</i>					
7	<i>Lacking sodium chlorid</i>					
8	<i>Lacking iron</i>					

EXERCISE 29

Problem. What is there in a seed that becomes a living plant?

What to use. Different large seeds (for example, beans, peas, peanuts, cotton seeds, castor seeds, horse-chestnuts), some dry, some soaked¹ for twenty-four hours; magnifying glass.

What to do. Examine outside of seed and note size, shape, and position of scar showing where the seed was attached to the fruit. This is the *hilum*. Look for a tiny opening through the waterproof coats (*testa*), called the *micropyle*. Examine any other surface peculiarities or structures.

Carefully remove the seed coats of two different seeds. Notice the two halves of the seed — the fleshy seed leaves called the *cotyledons*. These are joined to a pointed structure called the *hypocotyl*, part of which grows into the ground and becomes the root and part of which becomes the stem. Note the first bud, usually lying between the cotyledons and attached to both of them at the base. This is called the *plumule*, or *epicotyl*.

NOTE. All the structures inside the coat, or testa, of most of the seeds together make up the *embryo*, or young plant. Each part of the embryo corresponds to one of the main parts of a full-grown plant.

Record. Fill out the blanks on the next page with diagrams, making each drawing at least two inches in diameter. Label all the parts for which names are given in the study.

Questions. 1. In what way do the cotyledons resemble ordinary leaves?

2. In what ways do the cotyledons differ from ordinary leaves?

3. How would the hypocotyl have to change to resemble an ordinary root?

4. How does the plumule resemble the parts of a plant usually found aboveground?

¹ Add a few drops of formalin to the water in which the seeds are soaked, to prevent fermentation or decay.

EXERCISE 29 (Continued)

	NAME OF FIRST SEED -----	NAME OF SECOND SEED -----
<i>External view of surface showing hilum</i>		
<i>Embryo showing all the parts</i>		

EXERCISE 30

There are many kinds of plant structures besides *seeds* that are used for producing new individual plants, and that are really different. Pieces of potato containing eyes are sometimes called seeds, and so are grains, like wheat, barley, corn, etc.

Problem. How does a grain differ from a seed?

What to use. Corn grains, some dry and some cooked on the cob (and preserved in dilute formalin solution); magnifying glass; iodine solution.

What to do. Examine the grains, dry and cooked, and locate (1) the point of attachment to the cob; (2) the little spot at the opposite end at which the silk was attached; (3) the flat, shield-shaped area marking the position of the embryo.

Carefully remove the coat of a cooked grain without injuring any of the structure beneath. Note two rodlike structures appearing just below the surface of the embryo. The one pointing toward the cob is the hypocotyl; the one pointing toward the silk is the plumule, or epicotyl. The rest of the embryo is cotyledon.

Carefully break out the embryo from the rest of the grain. Note how the cotyledon part differs from the corresponding part in the seeds studied.

NOTE 1. The part of the grain left after removal of the embryo is called *endosperm*; it is a mass of food which is used by the embryo after it sprouts. Many kinds of seeds also have endosperm.

Cut a cooked grain through from the embryo side, passing through the plumule in some and through the hypocotyl in others; cut some through lengthwise, splitting down the face of the embryo. Place the cut grains in iodine solution for a few minutes. This will stain the grain so that the embryo is distinct from the endosperm.

Examine the cut surface of several grains, to make up your mind what the shape of the embryo is.

Record. Make diagrams called for in the table on the next page at least three times as large as the original object. Label in each drawing all the structures that have been mentioned in the study.

Questions. 1. What structures are present in both the seed and the grain?

2. What structures has the grain that are not present in the seed?

3. What structure has a seed that a grain has not?

4. What serves the bean or pea embryo in the way the endosperm serves the corn embryo?

NOTE 2. Plants whose embryos have two cotyledons are called dicotyls or dicotyledonous plants; those whose embryos have but a single cotyledon are called monocotyls or monocotyledonous plants.

5. Name six dicotyls.

6. Name six monocotyls.

7. What is your definition of a grain?

EXERCISE 30 (Continued)

<i>External views of corn grain</i>	<i>Face showing embryo</i>	<i>Side view</i>
<i>Sectional views of corn grain</i>	<i>Longitudinal section</i>	<i>Cross section</i>

EXERCISE 31

When the embryo has suitable conditions, it sprouts, or germinates. The small plant resulting is known as a seedling.

Problem. How do different seedlings break through the ground?

What to use. Various seeds — beans, peas, corn, squash; sand, sawdust, or soil; a box or boxes to hold sand; water.

What to do. Soak four varieties of seeds in water overnight; plant a few of each kind in a box of sand, sawdust, or soil; keep well watered.

Record. Make parallel drawings of several stages of growth of the seedlings showing behavior of homologous (corresponding) parts.

	1	2	3	4
NAME OF SPECIES:				
PART OF SEED	BECOMES IN SEEDLING			
<i>Cover</i>				
<i>Cotyledon(s)</i>				
<i>Epicotyl</i>				
<i>Hypocotyl</i>				

Questions. 1. What changes take place in the cotyledons as the seedlings develop?

2. On the basis of the limited data obtained from the four species studied, fill in the above table.

EXERCISE 32

It has been noted that seeds will start to grow with practically no food from the outside. All that is necessary is water, air, and suitable temperature. We have noted the large seed leaves in certain seeds (bean, pea), and also the endosperm, the great mass of food stored outside the cotyledon in the corn.

Problem. Do these structures, the cotyledons and the endosperm, have anything to do with the growth of the seedling?

What to use. Different kinds of very young seedlings; vessels of water.

What to do. After the seeds have germinated, remove varying portions of the cotyledon in different seedlings, from none to the whole. Remove varying portions of the endosperm, from none to the whole. Return to bottles or pan of water and record results in form of table.

KIND AND CONDITION	OBSERVATIONS						
	After First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Seventh Day
<i>Peas</i>							
1. Unaltered							
2. One cotyledon removed							
3. Two cotyledons removed							
4. $\frac{1}{2}$ of one cotyledon removed							
5. $\frac{3}{4}$ of one cotyledon removed							
6. $\frac{1}{2}$ of two cotyledons removed							
<i>Corn</i>							
1. Unaltered							
2. $\frac{1}{4}$ of endosperm removed							
3. $\frac{1}{2}$ of endosperm removed							
4. All of endosperm removed							

Conclusion. What seems to be the relation of the cotyledons or endosperm to the growth of seedlings?

EXERCISE 33

Just as the chemist has worked out tests for carbon dioxid and acids and alkalies, we have tests for many of the useful substances in foods — the nutrients. Among the nutrients are a class called carbohydrates (in which we find starch and sugar), the proteins, the fats and oils, and the mineral matters found in the ash after burning.

Problem. How does iodine (the solution used for the test) affect starch?

What to use. Starch; iodine solution; test tubes; flame.

What to do. Place a drop of iodine solution on a piece of starch. Stir a small bit of starch in cold water and pour into boiling water in a test tube; allow to cool; add a drop of iodine solution.

Results. Note any changes that take place.

Questions. 1. You have found out how iodine affects starch. What else do you need to know in order to be able to use iodine as a test for starch?

2. Is there any starch in the cotyledon of a bean?

3. Is there starch in the endosperm of the corn?

EXERCISE 34

Protein, a class of substances present in all protoplasm, and in lean meat and fish, can be found by a more difficult test. The teacher should perform this as a demonstration.

Problem. How does protein act when treated with the materials used in the xanthoproteic ("yellow-protein") test?

What to use. Protein, such as white of egg or cottage cheese; test tube; a source of heat; water; concentrated nitric acid; ammonia.

What to do. Place a small amount of protein in the tube, add a drop of concentrated nitric acid, rinse with water; boil; let cool; add several drops of strong ammonia.

Results. Note color after addition of nitric acid; then again after addition of ammonia. The appearance of these two colors indicates presence of protein.

NOTE 1. No other known substances produce these same color changes after treatment with nitric acid and ammonia.

Record. Describe results and give your conclusions.

Problems to work out. (1) Is there protein in the cotyledons of the bean? (2) in the endosperm of the corn? (3) in the cotyledon of the corn? Try white feathers, wool, skin of finger.

NOTE 2. Another test for protein that is often convenient is to burn or singe a bit of the material and then to smell for the characteristic odor of burnt hair.

Question. How do you account for this same odor in a blacksmith's shop?

EXERCISE 35

The grease-spot test is used to determine the presence of oil or fat. If you rub your fingers through your hair and press them to a sheet of paper, a translucent spot will appear. There are oil glands in the scalp which give off droplets of the material that registers on the paper.

Problem. What common grains or seeds contain oil?

What to use. Clean white paper; various kinds of grains and seeds (for example, corn, bean, pea, oats, peanut, barley, flaxseed, squash, cottonseed, rye, radish, castor bean); small mortar or other means of crushing seeds.

What to do. Crush or grind the seeds or grains separately. Place a quantity of the meal on white paper, writing name of seed used alongside. Arrange all the heaps of meal in order, and place the paper in a mild oven or other warm place, allowing the fat which may be present to melt down and flow into the paper.

Results will appear after the meal has been brushed away.

Record. Make a list of the materials tested and indicate opposite each whether fat (oil) is present or absent.

- Questions.**
1. What seeds contain large quantities of oil?
 2. Which of the seeds tested contain both oil (fat) and starch?
 3. How is fat rendered from beef or pork?
 4. How does a grease spot on paper differ from a water spot?

EXERCISE 36

Problem. How does gravity influence the direction of growing roots?

What to use. Two small glass plates (those made by cleaning negatives will serve very well); filter or blotting paper; radish or lettuce seeds; water.

What to do. Thoroughly moisten two or three sheets of blotting paper and cover one plate with it. Place several soaked seeds on blotter in different positions, and gently place glass plate over the seeds. It may be necessary to put bits of match sticks in the corners to prevent the glass from crushing the seeds.

Record. When the seeds have sprouted, observe and sketch direction of growth of roots; after twenty-four hours observe and sketch again and turn plate one fourth of the way around, as indicated. Repeat every twenty-four hours for several days.

What do you conclude concerning the relation of gravity to the direction of growth of roots?

Questions. 1. In what way do the stems seem to be affected?

2. How is the reaction of the root to gravity related to the life of the plant?

3. How is the reaction of the stem to gravity related to the life of the plant?

4. How can you distinguish between growing down and simply falling?

EXERCISE 37

Problem. Do all parts of the stem and of the root grow at the same rate?

What to use. Bean or pea seedling; india ink; brush; container for growing seedlings.

What to do. Paint lines of india ink equal distances apart on root and on shoot. Return to water and after twenty-four hours examine position of the lines.

Record. Compare later condition with first. Where does extension of growth show most? Where least?

Make diagrams to show what has happened, and the basis for your conclusion.

Questions. 1. Do all the parts of your body grow at the same rate?

2. Are the rates of growth the same all the time?

EXERCISE 38

Problem. Does light affect the direction of growth in a plant?

What to use. A geranium (or other potted plant); a sunny window.

What to do. Notice position of flat surfaces of the leaves and upper tip of the plant in relation to the window. Turn plant about 180° (halfway around). After twenty-four hours note carefully what changes there are in the position of the leaves and of the tip. Repeat at intervals of one or two days, until there is no doubt as to the relation between the light source and the growth of the plant.

Record. Tell what happened and your conclusions.

- Questions.**
1. Which parts of the plant seem to be most sensitive to light?
 2. Which side of the stem *grew* more rapidly, that in the light or that in the shade?
 3. Try to tell how bending is brought about in the stem of the plant?
 4. How are changes in position brought about in the leafstalk?
 5. Do all plants behave the same way with relation to light?
 6. Of what use to the plant is the reaction of light?

EXERCISE 39

We learned that air is a mixture of several odorless, tasteless, colorless gases, of different specific gravities. Instead of forming layers with the heaviest at the bottom and the lightest at the top, gases in contact spread through each other in all directions, or *diffuse*.

Problem. How readily can gases spread and mix (diffuse)?

What to use. Several volatile substances with distinct odors — for example, carbon bisulfid, perfume, chloroform, ether, alcohol, acetic acid.

What to do. Open a bottle of one of the substances in the middle of the room ; as soon as pupils in the farthest parts of the room detect the odor, make a note of the time. Repeat with each of the other substances.

Record. Make a table showing the time required for each of the gases to diffuse a given distance.

Questions. 1. What kind of gases seem to diffuse most quickly?

2. How does an electric fan affect the diffusion of gases?

3. What would be the practical effect if the gases in the air were not evenly diffused?

EXERCISE 40

Problem. Do liquids diffuse in the same way as gases do?

What to use. Transparent container for water (jar, beaker, glass); medicine dropper; red ink or a dye such as eosin solution.

What to do. Let the water in the beaker stand for twenty minutes to make certain that there are no movements or currents in it. Place a large drop of red ink (eosin) gently in the middle of the surface.

Record. Note what happens to the pigment placed in the jar of water. Describe final result. Make a diagram to show by means of arrows the direction followed by the current of pigment.

- Questions.** 1. In what ways does diffusion in liquids resemble diffusion in gases?
2. In what way does diffusion in liquids differ from diffusion in gases?

EXERCISE 41

Problem. How does a cell take in the water?

What to use.¹ Test tubes; glass tubing; thread or small rubber bands; celloidin; solutions of cane sugar, grape sugar (or glucose), salt; thin starch paste; white of egg.

What to do. Make an "artificial root hair" by pouring celloidin into a test tube until about half full, then pouring back into the bottle slowly, turning the test tube all the while, leaving a thin film lining. Blow into the tube to help evaporate the ether and alcohol in the solution of celloidin; when the film is dry, pour in a little water; gently poke the edge of the dried film and gently push it from the tube, being careful not to tear it. Place a few drops of water between the film and the glass and slowly work the film free from the test tube. Test the film for holes by blowing into it.

Different members of the class fill their sacs with different solutions — boiled-starch solution, dense sugar solution, white of egg, etc. Gently tie a glass tube in the end of the bag to serve as an indicator of changes inside the artificial root hair. Place in a jar of water.

Record. Fill in the following table:

NAME OF SOLUTION IN BAG	DID ANY MATERIAL DIFFUSE OUT OF BAGS?	WAS ANY MATERIAL ABSORBED INTO BAGS?
1.		
2.		
3.		
4.		

Questions. 1. Do all substances tried diffuse through the membrane?

2. Do all diffuse at the same rate?

3. Do all substances absorb water from their surroundings?

4. What seems to determine the rate of absorption?

NOTE. Diffusion of substances through a membrane is called *osmosis*.

5. Where do you know diffusion of liquids to take place?

6. Where do you know osmosis to take place?

¹ Since it is very difficult for us to study the actual workings of living cells directly, we shall use an "artificial root hair" for the present.

EXERCISE 42

Problem. What is the structure of the absorbing part of a root?

What to use. Flax or radish seeds; blue or green blotting paper; petri dishes, Syracuse dishes, or any convenient flat containers; magnifier and microscope. The pocket garden used in Exercise 36 will serve very well to grow the seeds.

What to do. Place seeds on moist blotter in container; cover and leave for two days.

Examine the roots of the seeds (1) with the unaided eye, (2) with a lens, and (3) under the compound microscope, low power.

Record. Make a large drawing of what you see in each of the above cases; note the location and relative size of the "root hairs."

- Questions.**
1. How many cells are there in a root hair?
 2. What is the relation between the root hairs and the skin cells?
 3. Estimate the size of the root hair.
 4. What is the form of the root hair?
 5. What is the advantage to the plant of these outgrowths on the root?

EXERCISE 43

Problem. What is the structure of a fleshy root?

What to use. A good-sized fleshy root (for example, carrot or parsnip); glass; eosin or red ink; water.

What to do. Place tip of root in dye; let it stand for twenty-four hours, then make a few thin cross sections and cut a few long sections. Find the *epidermis*, or skin, and the *central cylinder*, or wood. A portion between the epidermis and central cylinder is called the *cortex*, or bark; a cylindrical layer of cells between cortex and central cylinder is the actively growing portion, the *cambium layer*. Extending from the cambium toward the skin and toward the center are the *medullary rays*.

Record. Make a drawing of the cross section, two inches in diameter, and one of the long section; label all the parts named in the study.

Questions. 1. From specimen studied, along what paths do you think liquid passes upward through the roots?

NOTE. Plants like parsnip, carrot, etc. usually grow a large root and a head of leaves from the seed during the first season. During the following winter the root remains in the ground and the part aboveground dies away. With the second season a flower shoot develops rapidly and the fruit and seeds are formed at the expense of the food accumulated in the root the first season.

2. Why is the best time to gather fleshy roots for human food late in the fall or early in the spring?
3. Why should roots be stored in cool and dry places?
4. What advantage has a plant like the dandelion over those that start anew from seeds every season?
5. If microscopic preparations of small roots such as *Ricinus* (castor-oil plant) can be had, make microscopic study and compare with gross structure.

EXERCISE 44

The water taken in by the roots of a plant rises in the stem for several reasons. Three of these are (1) root pressure, (2) capillary attraction, and (3) the lifting force of evaporation of leaves, called transpiration.

Problem. Can water be absorbed by the root with enough force to raise it above the earth?

What to use. A potted hydrangea or other convenient plant with stem half an inch thick at the base; rubber tube for connection; glass tube; water.

What to do. Place flowerpot with plant in a tub of water so that the earth is covered. Cut the stem under water to prevent entrance of air bubbles; attach the glass tube above the stem with the rubber coupling. Take out of the tub and support the glass tube in a vertical position. Mark the level of water in the tube from time to time.

Record. Describe results of the experiment and give your conclusions.

Questions. 1. In what ways does absorption by the roots resemble osmosis?

2. Would water be absorbed more easily from a soil that had much material in solution or from one that had very little material in solution? Why?

EXERCISE 45

Problem. To find roots illustrating principal types.

What to do. Gather two or three roots of each of the types in the following table ; find the name of the plant to which each belongs, and note the conditions and habits of each plant.

Record. Complete the following table by adding sketches and notes on examples you have gathered.

KIND OF ROOT	EXAMPLES	1	2	3
<i>Taproot</i>	<i>Parsnip</i>			
<i>Fibrous root</i>	<i>Grass</i>			
<i>Bundled, or fascicled</i>	<i>Dahlia</i>			
<i>Adventitious (growing from stem)</i>	<i>Corn</i>			
<i>Climbing</i>	<i>Ivy</i>			

Questions. 1. What are the functions of roots ?

2. What use does man make of roots ?

EXERCISE 46

Plant foods are built up in the leaves by means of a kind of manufacturing process. Organic materials are built up chemically out of inorganic compounds. In the process of food manufacture, carbohydrates, of which sugar and starch are good examples, are the first substances put together.

Problem. Is the presence of air necessary for starch-making?

What to use. A healthy plant; some material to keep air from the leaves — vaseline, for example.

What to do. Keep the well-moistened plant in a dark closet for twenty-four hours; test a piece of a leaf for starch.¹ Coat both sides of a certain portion of a leaf, as a strip down the center, with a thick layer of vaseline. Place the plant in sunlight; at the end of the day, break off the leaf. Test for starch.

Record results and state conclusions.

NOTE. By careful experiments, scientists have found that it is that part of the air known as carbon dioxide which is used by plants in starch-making.

¹ To test a leaf for starch, boil it for a few minutes in water, then place for a few minutes in a large test tube containing alcohol (grain or wood) until all the chlorophyll, or leaf-green, has been removed. Immerse in iodine solution. (See Exercise 33 for starch test.) Since the fumes of alcohol are inflammable, it is well to carry them away from the source of heat by means of a glass tube in a perforated stopper closing the test tube.

EXERCISE 47

Problem. What is the relation of light to starch-making?

What to use. A growing plant; an opaque mask (made of black paper); pins; pieces of cork.

What to do. After keeping the plant in a dark closet for twenty-four hours, mask a portion of the upper surface of a leaf with a piece of the opaque paper, pinning through small portions of cork; place the plant so that the masked blade receives full and direct rays of sunlight for several hours. Remove the masked leaf from the plant; test for starch as described in previous exercise.

Record. Draw diagrammatic, shaded representation of what results after test; write your explanation of results.

EXERCISE 48

The green plastids which we noted flowing in the protoplasm when we studied the plant cells of the Elodea (Exercise 19) are sometimes absent in leaves or in parts of leaves. The coleus and certain other plants have variegated leaves of this character.

Problem. Has chlorophyl (leaf green) anything to do with the making of starch?

What to use. A plant having a variegated, partly green leaf.

What to do. Make a diagram of one leaf, indicating green area; keep the plant in sunlight for a few hours, then break off the leaf; remove chlorophyl as in Exercise 46; test for starch.

Record. Note the portion of the leaf that has built up starch; make a drawing and compare with your first sketch. Explain the results.

NOTE. The part that chlorophyl plays in the process of starch-making is not yet certain. In terms of a manufacturing process, the chlorophyl grains are the machinery of the factory. The sunlight *activates* the machinery or makes it work, and the raw materials (made up of compounds of the elements C, O, and H) are separated and recombined in the form of sugars and starches.

- Questions.** 1. What living things do you know that have no chlorophyl?
2. How do such plants and animals get their food?

EXERCISE 49

Make a plan for an experiment that will answer the question, Is water essential to the process of starch-making?

Make a plan for an experiment that will answer the question, Is carbon dioxide essential to starch-making?

After comparing notes in class, to select the most reliable and the most workable plan, work out the answer to one or both questions experimentally and make a complete report.

EXERCISE 50

Problem. What gas is given off by plants during starch-making?

What to use. A watered plant such as geranium or hydrangea; bell jar with large opening; cork; taper; matches; piece of glass for base; vaseline; candle.

What to do. Place corked jar over plant and lighted candle. After flame has gone out, prove that the air in the jar will not support combustion by tilting the cork and thrusting the lighted taper into the jar. Recork jar; place in sunlight and repeat test at close of another day of sunshine.

Record. Describe results and explain what changes were brought about in the air.

Questions. 1. When a flame is present we know that carbon dioxid is one of the results of combustion. What happened to the carbon dioxid produced by the candle?

2. Of what value are parks in a crowded city?

3. When are plants of value in a sleeping-room?

4. What is the value of green plants in an aquarium?

EXERCISE 51

From the result of the preceding exercises, compare the process of starch-making in a leaf (or other green plant part) with the manufacturing process of a factory.

FACTORS IN A MANUFACTURING PROCESS	CORRESPONDING FACTORS IN STARCH-MAKING
<i>Machines or tools</i>	
<i>Energy for driving machines</i>	
<i>Raw material</i>	
<i>Finished product</i>	
<i>Waste or by-product</i>	

Questions. 1. There is always water and carbon dioxid in the air ; why is not carbohydrate constantly being formed in the sunlight ?

2. What becomes of the starch that has been made by a leaf in the course of the day ?

3. How do water plants obtain their needed material for starch-making ?

4. How many hours out of the twenty-four could a plant work at food-making ?

EXERCISE 52

Go over all of your laboratory notes and make a list of all the necessary steps in the experimental solution of a problem.

Explain why you consider each step necessary.

EXERCISE 53

Water absorbed from the soil by the roots passes through tiny tubes, or ducts, in the roots and stems to the leaves, where a part is used in starch-making, while the excess passes off into the air.

Problem. Do leaves give off water?

What to use. Growing plant; rubber sheet or paraffin paper; twine; bell jar; vaseline.

What to do. Tie the rubber or paper over the pot of a well-watered plant; dry the inner surface of the bell jar and place over the plant, sealing down with vaseline. After twenty-four hours note changes that throw light on the problem.¹

Record. What has happened to answer the question?

Questions. 1. Why does it usually feel cool and damp in a forest?

2. How do trees help prevent floods?

NOTE. The process of water removal through the leaves is called transpiration.

¹ The experiment may be tried with a single healthy leaf by setting up as in B. Use a cardboard to separate the air chamber from the water bottle, and seal up the space around the leafstalk with paraffin or vaseline.

EXERCISE 54

Problem. How does water get out of the leaf?

What to use. A compound microscope; a coleus or geranium leaf; slides; cover glasses; water.

What to do. Strip a small piece of the lower epidermis of the leaf, mount in water on a slide, place a cover slip over the preparation, and examine both through low and through high power.

Record. Make a careful drawing of what you see;¹ label all you can make out.

Questions. 1. Can you suggest an advantage of the location of stomata on the under surface of the leaf?

2. Where would you look for the stomata of a lily pad?

NOTE. Cross sections of leaves show enlarged spaces just inside the stomata. Water evaporates into these spaces from the leaf cells, and the vapor diffuses out through the stomata.

¹ The special arrangement of cells leaving an opening in the skin is called a *stoma*, meaning mouth (plural *stomata*). The large cells surrounding the stoma are called guard cells. The stomata allow air to pass in as well as water (vapor) to pass out.

EXERCISE 55

We saw that through the actions of the roots water is made to rise above the surface of the ground (Exercise 44).

Problem. Can the transpiration from the leaves raise water in a plant?

What to use. Glass tube; water; sealing wax or paraffin; a living leaf; small dish of mercury.¹

What to do. Fasten the stalk of a vigorous leaf in the end of a glass tube with sealing wax or paraffin.

Fill the tube with water and place the open end in the mercury, avoiding the entrance of air bubbles.

Watch the set-up from time to time for any change in the level of mercury in the tube.

CAUTION. See that the end of the stalk is clean and free from the sealing material.

Record. Tell what happens and show what light it throws on the problem of the rise of water to the top of a high tree.

Questions. 1. Under what conditions would leaves give off the largest amount of water?

2. Find out the specific gravity of mercury and calculate the amount of water-raising represented by the change in the column of mercury.

¹ If mercury is not to be had, connect the apparatus as shown in the figure. Any water-raising effect resulting from the transpiration would be shown by the rise of water in the second bottle.

EXERCISE 56

Problem. What changes take place in a cracker when it is chewed in the mouth?

What to use. Soda crackers; test tubes¹; iodine solution; Fehling solution.

What to do. Gather some saliva in a test tube; test part of it for starch and part for grape sugar. Test a piece of dry soda cracker for starch and for grape sugar. Chew a piece of soda cracker for two minutes, being careful not to swallow any of it. Place a small amount of chewed cracker in each of two test tubes. Test for starch and for grape sugar.

Record.²

	SALIVA	UNCHEWED CRACKER	CHEWED CRACKER
<i>Starch</i>			
<i>Sugar</i>			

Questions. 1. What is the source of the sugar found?

2. How can you tell that it did not come from the saliva? from the teeth?

¹ You can increase the flow of saliva by chewing a piece of paraffin.

² Indicate *presence* by + and *absence* by 0.

EXERCISE 57

Problem. What physical changes result from the digestion of starch?

What to use. Four "artificial root hairs" made as described in Exercise 41; boiled starch paste, thin enough to pour easily; diastase¹; pancreatin; saliva (see note 1, Exercise 56); iodine solution; Fehling solution.

What to do. Fill the celloidin membranes with starch paste. Into one mix a small amount of diastase; into the second, some pancreatin; into the third, about a teaspoonful of saliva. Immerse each sac in water, as shown in diagram. Test the water surrounding each cell for starch and for reducing sugar. Record results. After twenty-four hours test again and record. Then test contents of each sac for starch and for sugar. Complete record in table.

Record.

	SURROUNDING WATER				INSIDE OF CELL	
	Fresh		After Twenty-four Hours			
	<i>Starch</i>	<i>Sugar</i>	<i>Starch</i>	<i>Sugar</i>	<i>Starch</i>	<i>Sugar</i>
1. <i>Starch paste only</i>						
2. <i>Starch paste and diastase</i>						
3. <i>Starch paste and pancreatin</i>						
4. <i>Starch paste and saliva</i>						

Conclusions. What is the answer to the problem?

Questions. 1. Can starch diffuse through a cell wall?

2. Can sugar diffuse through a cell wall?

3. What is the source of any sugar found in this experiment?

4. What can change starch into sugar?

5. Will starch change into sugar of itself?

6. How does digested starch differ from undigested starch?

¹ The diastase should be tested before used, as the commercial product sometimes contains a reducing sugar.

EXERCISE 58

Digestion of food in the human body takes place in (1) the mouth, (2) the stomach, and (3) the intestine. In each of these spaces there is at work a special digestive fluid : (1) the saliva, containing the ferment ptyalin ; (2) the gastric, or stomach, juice, containing the ferment pepsin ; and (3) the pancreatic juice, containing several ferments.

Problem. Which of the digestive fluids acts upon protein ?

What to use. Pieces of egg albumen¹ ; some saliva² ; a solution of pepsin ; a solution of pancreatin ; test tubes ; water ; absorbent cotton.

What to do. Place in the test tubes strips of albumen of about the same size. In one tube place water ; in the second, saliva ; in the third, pepsin solution ; in the fourth, pancreatin solution. Close tubes with cotton plugs. Place all in a warm place overnight ; note changes in the egg every day until one of the pieces is definitely eaten away.

Record. Indicate in the appropriate spaces the amount of change produced day by day in each tube.

	First Day	Second Day	Third Day	Fourth Day	Fifth Day
<i>Protein + Water</i>					
<i>Protein + Saliva</i>					
<i>Protein + Pepsin</i>					
<i>Protein + Pancreatin</i>					

Questions. 1. What solutions brought about the digestion of protein ?

2. Which solution acted most quickly ?

3. In what parts of the body may proteins be digested ?

¹ From the white part of a hard-boiled egg thin strips are cut with a sharp knife.

² See Note, Exercise 56.

EXERCISE 59

Problem. What digestive processes take place in the human body?

A study of the different nutrients and of the digestive system in man should leave us clear as to what happens normally to every part of our food after it is eaten. Make a diagram at least five inches long, showing all the important organs of the digestive system. On the left side of the diagram make a list of the organs and draw lines to indicate the corresponding parts of your diagram. On the right-hand side make a list of the food substances that are digested in each of the organs shown, and connect with a line to the corresponding part of the diagram.

Question. How is it possible for a person to continue to live after the stomach has been removed?

EXERCISE 60

Problem. To find the condition of my own teeth.

What to use. Small hand mirror to go into mouth ; larger mirror ; diagram of complete set of teeth.

What to do. Examine all your teeth with the two mirrors ; indicate on diagram all the incisors, canines, premolars, and molars.

Record. Locate the approximate position of any cavity by an arrow ($\rightarrow$). If any of your teeth are missing, shade the corresponding part of the diagram ($\bullet$). Mark position of loose or broken teeth with a X.

Questions. 1. (a) How many teeth are there in a full and complete set ? (b) How many (unshaded) teeth does your diagram show ? (c) Account for the lack of any teeth.

2. Did your teeth seem to be properly cleaned of (a) particles of food, (b) a hard deposit, called tartar ?

3. Suggest motion of toothbrush application that will (a) remove particles of food and (b) clean the surface of the teeth.

4. How can tartar be removed ?

5. Recommend course of action to be followed as a result of the study and record made in this exercise.

EXERCISE 61

Problem. What is the food value of the meals we eat?

What to use. A table of food values, such as Dr. Irving Fisher's 100-Calorie Portions Table (p. 96 of text) or Mr. Frank Rexford's One-Portion Table (p. 98 of text); a careful list of all the food eaten by two or three members of your family for one day.

What to do. Fill in a table like the following for each member of the family, making the calculations from the Fisher or Rexford table.

RECORD OF FOOD EATEN BY ----- ON ----- OCCUPATION -----						
	NAME OF FOOD	SIZE OF PORTION	WEIGHT OF PORTION	CALORIES FROM		
				Proteins	Fats	Carbohydrates
<i>Breakfast</i>						
<i>Luncheon</i>						
<i>Dinner</i>						
Totals						

Record. Have a committee of pupils compare on special sheet or blackboard the result of work of the class.

Criticize one of the dietaries, indicating its strong points and its weak points.

Show how it can be improved.

EXERCISE 62

Problem. What is the relative economy of different kinds of food?

What to use. Fisher's table (p. 96 of text) and a list of current prices of foods obtained from dealers.

What to do. Find out the price of ten different articles of food. By means of Fisher's table compute the price of 100 calories of each article and further calculate the amount of each food that can be purchased for 10 cents. Finally, distribute the food units contained in this amount of food by calories.

Record. Make your report on a table ruled off as below; bring to class for comparison with other students.

ARTICLE		PRICE PER UNIT GENERALLY SOLD	COST OF 100-CAL- ORIE PORTION	QUANTITY FOR 10 CENTS	CALORIES IN 10-CENT PORTION		
					Protein	Fats	Carbohydrates
Example	<i>Peanuts</i>	<i>5 cents per box of twenty-six</i>	<i>26:5::13:x x = 25</i>	<i>2 boxes 1.28 oz.</i>	<i>40</i>	<i>126</i>	<i>34</i>
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Questions. 1. Compare the papers of the class and decide what food gives the greatest amount of protein for the least money.

2. What food contains the largest amount of fuel for 10 cents?

3. List in the order of their economy the foods that you have named.

4. Which food gives nearest to a balanced meal for the lowest price?

EXERCISE 63

Problem. What structures does an insect use in breathing?

What to use. Some living insect in a bottle closed loosely with cotton or paper (a good-sized grasshopper or bumblebee will serve); some preserved specimens or some freshly killed large grasshoppers or moths; magnifying glass; microscope.

What to do. Watch the living insect with lens and note any movements of the posterior part of the body, known as the abdomen. Note the tiny openings on the sides of the abdomen — the spiracles.

On a preserved or freshly killed insect examine a spiracle with a compound microscope. Using a large grasshopper or moth, dissect out with sharpened needles, under water, the tubes leading from these spiracles — the tracheæ. Study under the microscope.

Record. Make an outline drawing of the side view of the insect, showing location of spiracles.

Describe the movements of the abdomen of the live insect.

Draw a sketch of the tracheæ that you observed in the dissection, under the microscope.

Questions. 1. What happens to air in tubes when the abdomen contracts? when it expands?

2. What structures in grasshoppers correspond to our nostrils? to our bronchial tubes and lungs? to our chest walls? to our diaphragm?

EXERCISE 64

Problem. How does the frog breathe?

What to use. A live specimen in a battery jar, or a freshly killed specimen; straw; dissecting needle; glass tube drawn out almost to a point.

What to do. Locate the nostrils and observe their movements during the breathing process. Note the movements of the floor of the mouth, under the jaw. Watch the frog as he seems to swallow and also watch the throat and the nostrils during this process. Observe the sides of the animal and see if you can correlate the various motions; that is, do the sides puff out when the throat puffs out or when it contracts?

On a freshly killed specimen note by probing with a straw where the nostrils lead. Does this help you to decide why the throat puffs out? At the rear of the mouth locate a raised spot, and with the dissecting needle pull one side away from the rest, thus disclosing a narrow slit, the glottis, in the middle of the elevation. Gently insert the glass tube in the glottis and, by blowing, inflate the lungs. Does this help you decide why the animal's sides puff out? Dissect out the lungs and the tubes that connect them, noting where the tubes (bronchi) join and form the trachea and where this one tube enters the mouth.

Record. Draw a picture of the nostrils and the lungs and tubes.

Questions. 1. Tell how air enters a frog's mouth.

2. How is air forced into the lungs?

3. How is air expired?

NOTE. The frog has no diaphragm as have human beings and other mammals.

4. What does the work of this structure?

5. What would happen if a frog's mouth were kept open indefinitely? Why?

6. How does the frog breathe when buried in the mud in winter?

EXERCISE 65

Problem. How does a fish breathe?

What to use. Living fish (goldfish, perch, or bream) in a battery jar; carmine; small pipette; preserved fish.

What to do. Observe the swallowing movements of the fish. See whether you can tell what happens to the water after it enters the mouth. Take up a small quantity of carmine suspended in water in the pipette. Lower the tip of the pipette gently below the surface of the water in the jar, and hold it until the fish's mouth is near it; then gently discharge the carmine into the water so that the fish will be likely to swallow some of it. (It will not hurt the fish.) See whether you can trace the course of the water that the fish swallows.

Cut off the flap on one side of the preserved fish's head. This flap is called the operculum. The feathery structures under the operculum are the gills. Study a single gill and find the bony arch, the raker, and the small subdivisions of the gill among which the water passes.

Record. 1. Draw side view of head of fish, and indicate by means of arrows the path taken by the water when the fish breathes.

2. Draw a single gill, enlarged.

- Questions.** 1. Where are the muscles located that set up the currents of water for the fish's breathing?
2. Why is it necessary to change the water or to keep green plants in an aquarium?
3. In what way does the breathing of the fish resemble that of the frog? In what way do they differ?
4. What has osmosis to do with the breathing of the fish?
5. Which part of the gill always faces the mouth? Which part always extends in the opposite direction? Can you tell how this arrangement is important?
6. What are the functions of each part of the gill?

EXERCISE 66

Problem. A comparison of breathing in different animals.

What to use. Laboratory notes on breathing; any sources of information about the breathing of animals, including man.

What to do. Compile information into the table below.

HUMAN ORGANS CONCERNED IN BREATHING	CORRESPONDING ORGANS OR PROCESSES IN			
	Paramecium	Insect -----	Fish -----	Frog
<i>Nostrils</i>				
<i>Bronchial tubes and tracheæ</i>				
<i>Lungs</i>				
<i>Diaphragm</i>				
<i>Process of inhalation</i>				
<i>Process of exhalation</i>				

- Questions.** 1. In what ways is breathing alike in all animals?
 2. How does breathing in animals resemble breathing in plants?
 3. How does breathing in animals differ from breathing in plants?

EXERCISE 67

Problem. What effect has moderate exercise on the rate of respiration?

What to use. Chart for keeping record of class.

What to do. As teacher keeps time for one minute, count number of breaths taken during the interval. After a brisk two-minute drill or setting-up exercise, count breaths as before for one minute.

Record your own count: *Before exercise* *After exercise*

Record. In the table below enter in appropriate spaces the number of students who took 12 breaths per minute before exercising, the number who took 13 breaths, and so on. Then record in the same way the number who took 12 breaths after exercising, the number who took 13 breaths, and so on.¹

BREATHS PER MINUTE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<i>Before exercise</i>																			
<i>After exercise</i>																			

Questions. 1. What is the lowest breathing rate in the class before exercise?

2. What is the highest breathing rate?

3. What is the average breathing rate?

4. What effect has exercise on the rate of breathing? Can you tell why?

5. Can you find any connection between age and the rate of breathing? between sex and the rate of breathing? between stature and the rate of breathing?

6. What besides exercise makes your breathing rate vary?

¹ You can show all the facts graphically by drawing a horizontal line across the appropriate space for *each* student who took a given number of breaths per minute. If the horizontal lines are equal distances apart (say an eighth of an inch), the heights of the columns will correspond to the number of students in each group.

EXERCISE 63

The sweat glands are constantly bringing perspiration to the surface of the skin, where the water evaporates immediately. But at high temperatures the perspiration comes to the surface faster than it can evaporate, and so the drops of fluid become visible. Whenever anything interferes with free perspiration, or with the evaporation of water from the surface, the temperature of the body is likely to rise and thus cause more or less serious discomfort.

Problem. How does the evaporation from the surface affect the temperature?

What to use. A small, thin watch glass; ether; alcohol or gasoline; water; a sheet of stiff paper or a fan; a thermometer.

What to do. 1. Place a few drops of water on the table; in this set the watch glass nearly full of ether; under the edge of the glass, in the water, place the bulb of the thermometer, after reading the temperature. Fan the surface of the ether until it has all evaporated. Remove the watch glass; examine the water and read the thermometer.

CAUTION. See that there is no open flame about while working with ether or gasoline.

2. Place a few drops of alcohol or gasoline on your finger and move your hand rapidly through the air; note what sensation you have regarding change in temperature.

Record. Describe the results found in 1 and 2. What do you conclude as to the relation of evaporation to temperature?

Questions. 1. What becomes of the heat that seems to disappear?

2. How does fanning help to keep cool?

3. Does a breeze or fanning cool the body when there is no moisture (perspiration) on the surface?

What is the reason?

4. What conditions in the air can interfere with rapid evaporation of the perspiration?

5. Do we perspire more on a muggy day or on a dry day? Why?

EXERCISE 69

The air cells of the lungs expose a large surface to the air which is breathed in. Through the membranes lining the air cells the exchange of gases takes place by osmosis. To keep up this gas exchange it is necessary that the membranes be kept constantly moist.

Problem. What effect has the amount of moisture in the surrounding air upon evaporation, or drying up?

What to use. Filter paper; two preserving jars; water.

What to do. Soak a piece of filter paper in water; divide it into two; fasten each piece on the under surface of one of the jar lids (use sealing wax or paraffin). In the bottom of one jar place water to a depth of an inch; leave the other jar dry; close the jars with the lids from which the wet paper is suspended.

Record. What is the condition of the two papers at the end of twenty-four hours? after forty-eight hours? What effect has the presence of water in the bottom of the jar upon the air in the jar? What is the answer to the problem?

- Questions.** 1. Why do clothes dry more readily on some clear days than on others?
2. What are the advantages (or disadvantages) of a dry atmosphere in warm rooms?

EXERCISE 70

Problem. In what local industries are the workers exposed to vapors, dusts, or fumes, that are harmful?

What to do. Make a survey of the community, fill out a blank like the one below, and bring to class for comparison with those of fellow students. After comparing notes make as complete a list as possible.

NAME OF INDUSTRY	NATURE OF THE HAZARD-	PRECAUTION OR SAFEGUARD EMPLOYED	SUGGESTIONS
Dupont T. N. T. Co.	Working with a poison that is absorbed through the skin	Workmen employed in short shifts and for limited time in T. N. T. Frequent medical observation and examination	

•

What to use. Any good-sized monocot stem, such as cane, corn, bamboo ; a good-sized dicot, such as willow, hickory, maple ; stained sections of young seedlings of corn and ricinus or other dicot herb.

In the microscopic sections compare the cell structure of the woody bundles.

CROSS SECTIONS

MONOCOTYLEDON		DICOTYLEDON
<i>Gross Structure</i>		
<i>Microscopic Structure</i>		

EXERCISE 71 (Continued)

LONGITUDINAL SECTIONS

MONOCOTYLEDON

DICOTYLEDON

Gross Structure

Microscopic Views

Questions. 1. Which has more pith, a monocotyledonous stem or a dicotyledonous stem?

2. How do the two classes of plants differ as to the character of the wood?

3. What is there about the structure of the dicot that suggests the possibility of longer life and larger growth?

EXERCISE 72

Problem. What are the important differences between monocotyledons and dicotyledons?

What to use. Specimens; charts or results of studies to furnish data for following chart.

What to do. By means of words or diagrams or both fill in the following table, naming the plants studied in each case.

	MONOCOTYLEDONS		DICOTYLEDONS	
	<i>External Structure</i>	<i>Internal Structure</i>	<i>External Structure</i>	<i>Internal Structure</i>
SEED				
STEM	<i>Cross Section</i>	<i>Long Section</i>	<i>Cross Section</i>	<i>Long Section</i>
LEAF	<i>Shape and Veins</i>	<i>Cross Section</i>	<i>Shape and Veins</i>	<i>Cross Section</i>

Questions. 1. How many cotyledons in the monocotyledonous seed? in the dicotyledonous seed?

2. How do the veins of the leaf run in the monocotyledon as compared with the midrib? in the dicotyledon?

3. What is a polycotyledon?

EXERCISE 73

There are ducts, or vessels, through which fluids may pass in the wood part of a dicot stem and in the bark part of the stem. Some of these ducts carry material up from the roots to the leaves; others carry material from the leaves to the roots.

Problem. Which currents are carried by the vessels of the bark?

What to use. Two twigs of willow; jar of water; sharp knife.

What to do. Cut off carefully a girdle of green bark about an inch long, near the lower part of one twig; place both twigs in water for a few weeks and observe from time to time. Keep replacing evaporated water, so that the water remains at a constant level.

Record. Note any changes that take place in any part of either stem, or at the upper or the lower edge of the cut surface. From the results observed, tell whether the bark vessels carry materials up the stem or down.

Questions. 1. Explain reason for any change noted in the above experiment.

2. Why does a tree die when the bark is girdled? Why does it not die immediately?

3. Why didn't the willow twig die after girdling?

4. Is maple sirup obtained from the ascending sap or from the descending sap? How can you tell?

5. Trace the upward and downward course of sap in a plant.

EXERCISE 74

In addition to the pressure resulting from the action of osmosis in the root, and in addition to the apparent "pull" resulting from the transpiration of water from the leaf, liquids are said to rise in stems because of the capillarity of the vessels.

Problem. What is the relation between the diameter of a vessel and the height to which liquids will rise in it without additional force being applied to them?

What to use. Glass tubes of various diameters; vessel containing water that has been colored with a few drops of red or blue ink.

What to do. Place the glass tubes vertically in the liquids; note the height to which the liquid rises in each tube. Estimate the relative sizes of the tubes, in internal diameter.

Record. Make a diagram showing the approximate sizes of the tubes used and the heights to which the liquid rose in each. Tell what relation you find between the diameter of a vessel and the extent to which a fluid will be drawn up in it.

Questions. 1. Would the vessels, or ducts, of a plant raise water as much as glass tubes, or more, or less? Why?

2. For what practical purposes is capillary attraction used?

EXERCISE 75

Problem. What is the make up of the human blood?

What to use. Compound microscope; glass slide; cover glass; gas or alcohol flame; sharp needle; normal salt solution (made by dissolving about a teaspoonful of common salt in a pint of water).¹

What to do. Press the thumb hard against the joint of the index finger until the skin is tight and red. With the other hand pass the needle through the flame. After waiting a moment for it to cool, prick the tight skin of the thumb with a smart stroke. Collect the drop of blood in the middle of the glass slide. Add a drop of salt solution. Cover with the cover glass. Examine under the microscope, first with the low power, then with the high.

Record. Make a drawing to show all the different structures you can find.

NOTE. The yellowish disks are the red corpuscles. Larger, irregular bodies, not so numerous, are the white corpuscles. The clear liquid in which the corpuscles float is the plasma. These three are the chief constituents. There are other structures in the blood, but they are harder to see.

Question. What element of the blood is deficient in a pale person who is said to be anæmic?

¹ It is not necessary to prepare salt solution for your own use; there is probably some on hand in the laboratory.

EXERCISE 76

Problem. What takes place when the blood clots?

What to use. Fresh blood from the butcher or the slaughterhouse, to which a few drops of formalin have been added as a preservative; two glass beakers or battery jars with covers; an egg-beater or a bundle of thin twigs; water; covers for jars.

What to do. Place equal quantities of blood in the two vessels. Set one (*A*) aside, covered, to remain undisturbed. In the other (*B*) beat up the blood with the egg-beater or the twigs. Draw out what clings to the beater after a few minutes. Cover and set vessel *B* aside to remain undisturbed.

Wash the material that clings to the beater in fresh water. On the following day examine the contents of *A* and *B*.

Record. Describe the stuff that has been removed from the blood by the beating. What changes have taken place in *A*? Make a diagram to show results. What has happened in *B*?

Questions. 1. What is there in *A* that was not there the day before?

2. Where did it come from?

3. Remove the clot from *A* and wash in fresh water; what change does the washing bring about?

4. What is now absent from *A* that was there on the previous day? What has become of it?

NOTE. The shiny stuff removed from the blood by beating is fibrin. This forms the clot. Plasma contains a substance called fibrinogen; when this is brought in contact with the air, it becomes fibrin. Beating brings air in contact with all parts of the plasma and removes the fibrin as fast as it is formed. The clear fluid in the jar after the *clot* is formed is called *serum*.

5. What has become of the corpuscles in *A*?

Blood = plasma + corpuscles

Plasma = serum + fibrinogen

6. Why do small cuts usually stop bleeding in a short while? Why do they sometimes continue to bleed for a long while?

EXERCISE 77—DEMONSTRATION

The blood carries not only food and wastes but also the gases involved in respiration.

Problem. How do gases of the air affect the blood?

What to use. The blood from which the fibrin has been removed,¹ in two beakers; oxygen; carbon dioxid; rubber tube; glass tube.

What to do. Connect the glass tube by means of the rubber tube to the tank or generator for supply of carbon dioxid. Pass a current of the gas through the blood (*A*) by placing the glass tube in the blood. After noting the action for a few moments pass oxygen through the blood in the second beaker (*B*). After comparing effects reverse the procedure; that is, pass oxygen through *A*, and carbon dioxid through *B*.

Record. Describe the appearance produced by oxygen and the appearance produced by carbon dioxid. Tell what happened to the appearance of oxygenated blood that was treated with carbon dioxid and what happened when this was again treated with oxygen.

NOTE. Blood contains an iron-bearing protein in the red corpuscles called hemoglobin, which has a decided affinity for various gases and forms with oxygen a chemical compound called oxyhemoglobin. In the presence of carbon dioxid, hemoglobin releases oxygen and takes up carbon dioxid.

¹ Whole blood may be used in which clotting has been prevented by the addition of one part sodium oxalate solution (3.8%) to nine parts blood.

EXERCISE 78

The blood is not only constantly moving but also constantly changing its composition, for all the time materials are being removed from it and other materials are being thrown into it.

Problem. What are some of the changes that take place in the blood at the various points in its course?

What to do. Gather all necessary information and fill in the following table :

SOURCE OF THESE MATERIALS	MATERIALS GIVEN TO THE BLOOD	NAME OF ORGAN	MATERIALS TAKEN OUT OF BLOOD	WHAT BECOMES OF THESE MATERIALS
		<i>Organs of head</i>		
		<i>Thyroid</i>		
		<i>Lungs</i>		
		<i>Muscles of arms</i>		
		<i>Stomach</i>		
		<i>Intestine</i>		
		<i>Large intestine when clogged</i>		
		<i>Suprarenals</i>		
		<i>Kidneys</i>		
		<i>Liver</i>		
		<i>Spleen</i>		
		<i>Legs</i>		

EXERCISE 79

The circulating fluid, the blood, is inclosed in a system of tubes, arteries, veins, and capillaries. The motion of the stream is caused by the pumping (muscular contraction) of the heart through which the stream passes. The action of the heart is influenced by the chemical condition of the blood, and this in turn is influenced by our breathing and by the work of the body.

Problem. How does moderate exercise influence the rate of the heart's beat?

What to use. Chart for keeping record of class.

What to do. As the teacher keeps time for one minute, count the number of heart beats (pulse) during the interval.¹ After brisk two-minute drill or setting-up exercise, count the pulse as before for one minute.

Record your own pulse : *Before exercise* *After exercise*

Record. In the table below enter the number of students whose pulse was below 75 per minute before exercising, the number whose pulse was between 76 and 80 inclusive, and so on. Then record in the same way the pulse rates after exercising.²

PULSE RATE	75 OR UNDER	76 TO 80	81 TO 85	86 TO 90	91 TO 95	96 TO 100	101 OR OVER
<i>Before exercising</i>							
<i>After exercising</i>							

- Questions.** 1. What is the lowest pulse rate of the class before exercising? after exercising?
2. What is the highest pulse rate before exercising? after exercising?
3. What is the average pulse rate for the class before exercising? after exercising?
4. What chemical changes are brought about in the blood by exercising?
5. What besides exercise can make your pulse become faster or slower?
6. What changes do these things cause in the chemical condition of the blood?
7. What is the advantage or disadvantage of a changing pulse rate during exercise?

¹ You can easily find your pulse by pressing your finger directly in front of your ear.

² See note in Exercise 67.

EXERCISE 80

Protoplasm in plant and animal cells is constantly producing substances that are of no further use to it, or separating useless substances out of the material received. Some of these are passed out of the cells and out of the organism; others are passed out of the cells but gathered up in parts of the organism where they cannot injure the living parts.

Problem. What is the character of some of these waste substances?

What to use. Petals of pansy; stem of horsetail, or scouring rush (*Equisetum*); Indian turnip (*Arisæma*); microscope; slides; cover glasses.

What to do. Mount piece of pansy petal, of scouring rush, and of Indian turnip on slides and examine with the microscope. Note colored fluids and colored particles in the pansy; crystals of silica in the horsetail; crystals of lime oxalate in the Indian turnip. Place a tiny bit of the Indian turnip on the tip of your tongue and note sensation.

Record. Make clear diagrams showing each kind of body found in your study; label structure shown.

NOTE. The peculiar taste of the Indian turnip is due to the action of the fine crystals shown in some of the cells; these crystals are called raphides (three syllables).

- Questions.**
1. What substances are formed in living cells that are not injurious to protoplasm?
 2. Name some substances that are stored up in cells and are of use to the organism.
 3. How can you tell whether a given substance produced in a cell is a waste product?
 4. What substances produced by protoplasm are not solids?

EXERCISE 81

In the simplest plants and animals the cell surface is at the same time the absorbing area and the excreting area. In higher organisms many of the special surfaces are both absorbing and excreting surfaces—for example, the lining of lungs, the leaves of plants.

Problem. Is the root of a plant an excreting organ as well as an absorbing organ?

What to use. Young seedlings of bean or corn; two bottles of water; phenolphthalein solution.

What to do. In one bottle place a small quantity of phenolphthalein that is colorless; in the other, enough alkaline (red) phenolphthalein to make the water barely pink. In each bottle insert the roots of a live seedling. Note changes from time to time.

Record. Tell whether the roots give off any substance, and, if so, whether it is acid or alkaline.

Questions. 1. Aside from getting rid of waste matter, what use might a secretion of substances by the root be to the plant?

2. Compare the output from your lungs with the output, if any, of the roots, using experimental methods.

EXERCISE 82

Problem. What is the structure of an animal kidney, and what work does it do?

What to use. A beef or sheep kidney.

What to do. Draw the outside view of the kidney about three inches long. Cut through the kidney lengthwise and make a second drawing; label the arteries leading blood to the kidney, and veins leading blood from the kidney. In section, note the funnel-shaped cavity in which the fluid is gathered by the gland action of the kidney. Note the tube which leads the waste to the bladder — the ureter. Study a microscopic section or chart of one of the tubules found in the kidney — a glomerulus — and draw below.

- Questions.**
1. In what way is the action of the kidney like that of a gland — for example, the liver?
 2. In what way is the action of the kidney different from that of a gland?
 3. What are the physiological differences between the wastes removed from the body by the kidneys and those removed by the large intestines?

EXERCISE 83

Problem. What is the structure of the skin?

What to use. A good microscopic section or a chart or a model.

What to do. Study the section of the skin and note a hair follicle, oil glands, a sweat gland, nerves and nerve endings, and the different layers of skin.

Record. Make a carefully labeled drawing showing all the structures mentioned.

Questions. 1. Is the excretion of the skin acid or alkaline? How do you know?

2. What is the effect of too frequent washings with soap? Why not use laundry soap on the skin?

3. What is the effect of too infrequent washings?

4. What is a corn? Why does it hurt? Why can we cut the surface without causing pain?

5. What animal coverings correspond in type to our skin? What animal coverings are of a different type?

EXERCISE 84

Gather material for completing the table below with suitable sketches or statements of fact ; select four types of animals besides those named.

SIX TYPES OF EXCRETORY ORGANS

LOCATION IN BODY	NAME OF ORGAN	STRUCTURE OF ORGAN	HOW THE ORGAN WORKS
1. <i>Paramecium</i>	<i>Contractile vacuole</i>		
2.			
3.			
4.			
5.			
6. <i>Mammal (man)</i>	<i>Kidney with glomerules</i>		

EXERCISE 85

Plan an experiment or a study to show the effects of fatigue in some kind of work or play.
Bring plan to class for comparison with those of other students and for criticism before carrying it out.
Make a complete report on the method, results, and conclusions.

EXERCISE 86

Some of the movements performed by human beings and other animals result from the contraction of muscles over which there is no direct control (for example, heart movements, stomach movements). Other movements result from the contraction of muscles which we can sometimes control, but which ordinarily act without any attention from us (for example, the eyelid movements, diaphragm movements). In still other cases voluntary, or striped, muscles contract as a result of some stimulation, without our being able to control them at all. Such forced movements are called reflexes.

Problem. Can we control any of our reflexes?

What to use. Live human beings with definite reflexes. (Students work in pairs.)

What to do. 1. *The knee-jerk reflex.* Sit comfortably on a chair, in relaxed position, with one knee crossed over the other. Strike the tips of the fingers just below the kneecap of the upper knee and note movement of foot resulting.

(It may require several trials to locate the exact spot and to learn the best way of striking. A good way to proceed is to hold a ruler firmly with the edge right under the kneecap, and then to tap the opposite edge.)

When you have made sure that you can produce the knee jerk, repeat several times, the subject trying to prevent the jerk while the operator produces the stimulation.

2. *The winking reflex.* Bring finger quickly in front of subject's eye, without touching it or the eyelashes. Note movements of the eyelids. Touch eyelashes gently from the side or from above with a feather or light straw so that the subject cannot see the object approaching. Repeat, with the subject trying to prevent the wink.

3. *Grasping reflex.* If it is possible to have access to a very young infant, note the baby's reaction to a solid object (stick, finger) placed across the palm of the hand. Find out whether the reaction is uniform; whether it depends upon the character of the stimulating object — hard or soft, large or small, rough or smooth, etc. With a spring scale fastened to the object that the baby clasps, measure the force of the grip; that is, find out how hard one must pull to force the object out of the baby's hand.

Record. Describe the results of the stimulation in each case and of the attempt to prevent the reactions from taking place. What is the answer to the Problem?

NOTE. A reflex is a form of movement that depends upon certain nerve connections which are inborn with other structural characters of the organism. The reflex system consists of a receptor (that is, a receiving element), an effector (that is, an effect-producing element), and a connecting element. In each of the three elements there is always a nerve part; in the receptor there is also a special sensitive portion; and in the effector there is a muscular (moving) portion or a glandular portion.

EXERCISE 86 (Continued)

- Questions.** 1. Can you control the tingling produced when the funny bone is struck?
2. What can you do to prevent shivering when chilled?
3. Make a list of all the reflexes you can observe in various animals, and add to it from time to time.

EXERCISE 87

In animals with a brain there is neither consciousness of any sensation or pain, nor control of movements, except through the action of brain cells. Nevertheless, many stimuli produce responses, and many connected movements can be performed, after the brain is removed or after its connection with the other organs has been broken. This is illustrated by the chicken that runs around after the head is cut off, or by the snake that moves about and withdraws from disturbing contacts after the head is removed.

Problem. Can an animal make useful movements without the action of its brain ?

What to use. A frog from which the brain has been cut away while under the influence of chloroform. Some dilute hydrochloric acid.

What to do. Suspend the frog by the lower jaw from a suitable support. Touch the side of the body lightly with a straw and note any reactions. Place a small piece of filter paper moistened with very dilute acid on the side of the body, and note reactions. Place the frog on a table in a sitting posture and tickle the sole of the foot ; note response.

Record. Describe the reaction of the frog to the various stimuli applied, and show how any of them might be considered of value to a frog under natural conditions.

Questions. 1. Recall two changes in your own behavior which may be of use, but over which you have no control.

2. What reactions to stimuli do you know in your own body that are of no use to you ?

EXERCISE 88

The sensitiveness of living things depends upon the irritability of protoplasm ; but the sensitiveness of a particular organ or area of a many-celled animal depends upon the distribution of special nerve-endings in that part.

Problem. Are some parts of the body surface more sensitive to touch than other parts ?

What to use. Two students working together ; a pair of dividers ; a ruler.

What to do. Open dividers about an inch. With the subject blindfolded, apply the two points *at the same time* on some part of the skin surface, and again but one point. The subject is to tell whether one or two points have been touched. Proceed in this way, opening or closing the dividers as needed, until you know the shortest distance that can be distinguished as two separate points. Repeat on different parts of the body.

Record. Tell the smallest separation between two points that you and your partner can distinguish by touch in the various regions, using millimeter or sixteenth of an inch as unit.

	WRITER	FELLOW WORKER
<i>Back of hand</i>		
<i>Palm of hand</i>		
<i>Tip of index finger</i>		
<i>Back of neck</i>		
<i>Face</i>		
<i>Tip of tongue</i>		

Questions. 1. Of what practical significance are the differences among the various regions ?

2. Of what practical significance are the differences among various people ?

3. What other differences may there be between people as to the sense of touch ?

EXERCISE 89

Sensitiveness to heat or cold, on the surface of the body, depends upon the presence of *specific* nerve endings, which are distributed rather unevenly in the skin.

Problem. (1) What is the distribution of the hot points and of the cold points in different parts of the skin? (2) Is there any relation between the positions of hot points and cold points?

What to use. Some pieces of wire or wire nails, about two inches long; some hot water (about 80°C.); some cold water (from 5° to 10°C.); two students working together.

What to do. Keep the nails in the water, some hot and some cold, except while in actual use. Touch the tip of a hot nail lightly to the skin of the palm of the hand (using the lines on the skin as a guide), then about one eighth of an inch farther, and so on, noting at each contact whether there is a distinct sensation of heat. Locate in this way, on the palm of the hand, from twenty to thirty hot points. Do the same on the cheek or on one of the fingers. Repeat with the cold nails. Change to a fresh nail as soon as the temperature of the one in use becomes too much like that of the surrounding air.

Record. Make a diagram of the areas studied. Locate the distribution of the hot points by means of red-ink dots, and that of cold points by means of black dots. Describe the results and answer the two questions in the Problem.

Questions. 1. About how close together are the hot points on the skin?

2. Which kind of nerve ending is more frequent, the cold-perceiving or the hot-perceiving? Would this be true in all parts of the body?

EXERCISE 90

The skin, including the mucous lining of the mouth and nose, can perceive several kinds of sensations besides that of touch. Just as some parts of the skin are sensitive to heat and others to touch, so different parts of the tongue are sensitive to the different kinds of taste, of which four are commonly distinguished — sour, sweet, salt, and bitter. The sensitive elevations on the tongue are called papillæ.

Problem. What is the location of the papillæ which are sensitive to the different tastes?

What to use. Four *very dilute* solutions: salt, sugar, vinegar or citric acid, and quinine or aloes; glass tubes drawn to a fine point, rounded off; water; two students working together.

What to do. With the subject blindfolded, place tiny drops of the different solutions on various parts of the tongue, following a systematic plan, and have the subject tell what sensation is produced by each drop. Occasionally introduce plain water. After the drop, have subject rinse mouth with water; rinse tip of tube if it comes in touch with the tongue.

Record. Make a diagram of the tongue and locate the distribution of the different kinds of papillæ, using colored ink or crayon, or different symbols or letters, to distinguish the four kinds.

Questions. 1. Is it possible to distinguish two or more tastes at the same time?

2. Do substances of different taste ever interfere with our recognizing tastes?

3. How does the order in which different substances are placed in the mouth influence our perception?

4. Under what conditions would it be possible to put a bit of salt or sugar in the mouth without tasting it?

EXERCISE 91

With only four kinds of taste sensations in the mouth, how is it possible for us to distinguish such a great variety of food substances? The fact is that most of the things we relish or dislike affect us through the nerve endings in the nose, not through those in the mouth. We discover flavors through odor rather than through taste.

Problem. Is it possible to distinguish flavors with the nose passages closed?

What to use. Various spices, condiments, ground cereals, fruit juices, flavoring extracts, beef juice, etc.; water; two students working together.

What to do. With the subject blindfolded and holding the nose firmly with the fingers, place successive drops or fragments of the various materials to be tried on the tongue, and have the subject identify them if possible. Rinse the mouth after each trial, before opening the nose. In case of inability to identify, open the nose before removing substance. Have both students take turns as subject.

Record. Keep a close record of the materials tried and the results of each trial, whether a successful identification, a failure, or a partial success.

NOTE. The nasal passages connect with the pharynx, the cavity back of the mouth; but with the nostrils closed it is impossible for a current of air to carry materials from the mouth to the sensitive odor area.

- Questions.**
1. How is it possible to be sensitive to flavors but not keen as to tastes?
 2. What effect has a cold in the nose upon our appreciation of food?
 3. Which class of sensations more easily affects our feelings of pleasure or disgust — taste or odor?

EXERCISE 92

The eye in backboneed animals and in certain mollusks (the octopus, for example) consists of a *lens* that projects an image upon a sensitive surface, the *retina*. The focusing, instead of being brought about, as in a camera, by changing the distance between the lens and the retina, is brought about by changing the convexity, or bulge, of the lens. Very few human eyes are perfect, although most of them are quite usable for all ordinary purposes. The most frequent defects are nearsightedness and farsightedness, and an unevenness of the curvature called astigmatism.

Problem. What condition of the eye brings about farsightedness or nearsightedness?

What to use. A convex lens ; a vertical screen or sheet of paper held in a vertical position ; a ruler.

What to do. Support the lens in a vertical position a measured distance from the window—say 100 or 120 inches. Place the screen back of the lens and move it backward and forward until you have a clear image of the window. Measure the distance between the lens and the screen ; this is the *focal distance*. Now bring the lens five or six inches *nearer* the window, focus again, and measure the focal distance. Move the lens five or six inches *farther* from the window and find the third focal distance.

Record.

DISTANCE OF OBJECT FROM LENS	FOCAL DISTANCE
----- <i>in.</i>	<i>in.</i>
----- - 5 <i>in.</i> =	<i>in.</i>
----- + 5 <i>in.</i> =	<i>in.</i>

From the measurements made, can you tell what condition of the eyeball brings about farsightedness and what condition brings about nearsightedness?

Questions. 1. If the eyeball is too short, what can be done to save eyestrain?

2. If the eyeball is too long, what can be done to save eyestrain?

3. Why is a person more likely to need spectacles at an advanced age than at an early age?

EXERCISE 93

There are many organisms that respond to light without being able to see things as we see them, and some of them do not even have eyes.

Problem. How does an organism without eyes respond to light?

What to use. Live earthworms; glass or enamel-ware dish; some earth.

What to do. Place earthworm in empty dish which has been moistened. Hold it so that the light strikes it, and note the character and direction of its movements. Change position of dish to get illumination from different directions. Place earth in the dish and the worm on top of the earth; note whether the movements with relation to light are different on the earth. After the animal has started to burrow, note the effect of stronger or weaker illumination on the exposed parts.

Record. Describe the movements of the animals under different conditions and degrees of illumination.

- Questions.**
1. What other organisms without eyes do you know to be sensitive to light?
 2. Can you tell whether the front end or the rear end of the earthworm is more sensitive?
 3. How can you tell that the movements observed were not responses to odor?
 4. What other forces appear to influence the movements of the earthworm besides light?

EXERCISE 94

Vibrations of certain kinds are received through the ear and interpreted as sound. In different kinds of animals these vibrations are perceived through other kinds of organs, as by hairs on the antennæ of mosquitoes and the "drums" on the front legs of crickets.

Problem. What kinds of ears have animals other than mammals?

What to use. Living or preserved frog and grasshopper; magnifier.

What to do. Study the external eardrum of the frog and the tympanum of the grasshopper on its first abdominal segment, for size, shape, and rigidity or flexibility. If you have live specimens, determine whether they are sensitive to sounds that are different in pitch, loudness, or other quality.

Record. Describe results of your observations. Make diagrams showing structures.

- Questions.**
1. What organisms do you know that are not affected by sounds?
 2. How do you know they are not affected?
 3. Under what living conditions would perception of sounds be of no use to an organism?
 4. What practical applications are made of the principle of vibration illustrated by the action of an eardrum?

EXERCISE 95

Problem. Do the two ears of a person differ from each other in acuteness of hearing in the same way as the ears of different people do?

What to use. A class of students; a watch with a reasonably loud tick; a tape measure.

What to do. Blindfold each person in turn. Bring watch slowly toward the right ear until the subject can just begin to hear it; measure the distance. Repeat for the left side.

Record. Distance in inches at which right ear detected tick; left ear

Make a table showing, by the distance in inches at which the tick was heard, the relative acuteness of hearing of each subject for the right ear and for the left ear, and the *difference* between the two.

RIGHT EAR	LEFT EAR	DIFFERENCE	RIGHT EAR	LEFT EAR	DIFFERENCE	RIGHT EAR	LEFT EAR	DIFFERENCE

1. What is the average difference between the two ears?
2. What is the range of variation between the best and the poorest right ear?
3. What is the range of variation between the best and the poorest left ear?
4. What is the average distance for the right ear?
5. What is the average distance for the left ear?
6. Why is the difference between the averages less than the average difference?

Questions. 1. In what other respects besides acuteness do people's hearing sensations differ?

2. What practical use can be made in school of the fact that some hear so much more easily than others?

3. What practical use can be made of this fact outside of school?

4. What is meant by the statement "If there were no ears, there would be no sound"?

EXERCISE 96

The semicircular canals are our balancing organs, as changes in their positions result in a stimulation of nerve endings in their lining.

Problem. How sensitive is an animal to changes in its position?

What to use. A live frog in a battery jar; lampblack; absorbent cotton; vaseline.

What to do. 1. When the frog is at rest, slowly rotate the jar to right or left (30° – 45°) without shaking it; reverse the movement. Note reactions of frog. Hold the jar up so that you can see the side of the animal, and tilt the jar forward and backward, noting reaction. Hold the jar up so that you face the frog, and tilt it to the right and to the left, noting reactions.

2. To see whether any of these responses are influenced by *sight*, mix a little vaseline and lamp-black, and rub the mixture into a piece of moist absorbent cotton. With this pad you can blindfold the frog without hurting or irritating it. (Repeat the displacements as in 1.)

Record. Describe the responses of the frog to changes in bodily position, and try to answer the question in the Problem.

Questions. 1. What evidence did you discover that the frog is influenced by the *direction* from which the light strikes it?

2. How would you find out whether the frog would behave in the same way *if it used its eyes only*?

3. What practical use can be made of the fact that some people are more sensitive to changes in position than others?

4. What evidence is there that, besides the semicircular canals, other organs and sensations help us to keep erect and walk straight?

EXERCISE 97

We saw (Exercise 86) that some of our reflex, or instinctive, movements result from the contractions of muscles which we can control. We can produce some of these movements at will, and we can also inhibit, or prevent, some of the movements.

Problem. How many trials does it take to overcome the winking reflex?

What to use. A sheet of glass; a rubber-tipped pencil or stick; two students working together.

What to do. Have subject hold pane of glass in front of face while operator from time to time strikes opposite side of glass before one or the other eye. Subject tries to keep from winking, confident that pencil cannot reach him. Note number of strokes before there is complete control. Change off.

Record. Describe observations and results.

How many attempts were necessary to secure complete inhibition?

How many attempts were necessary for your fellow worker?

Tabulate results for the whole class:

NUMBER OF TRIALS												
NUMBER OF STUDENTS FOR EACH SCORE												

What was the highest number of trials?

What was the lowest number of trials?

What was the average number of trials?

Questions. 1. What is the advantage of being able to overcome an impulse within a short time or after a few trials?

2. What is the disadvantage?

3. Do boys or girls learn to control their impulses more readily? How do you know?

4. What kinds of inhibitions are established most easily? What kinds least easily?

5. What evidence is there that other animals can learn to overcome natural impulses?

EXERCISE 98

Below are the names of ten organisms, including four kinds of plants and six kinds of animals.

At the top of each blank column enter the name of a process or activity that all ten living things show in common. In the appropriate spaces indicate briefly the organs or methods by which the named activities or processes are carried on.

ORGANISM					
<i>Ameba</i>					
<i>Yeast</i>					
<i>Starfish</i>					
<i>Fern</i>					
<i>Oyster</i>					
<i>Cabbage</i>					
<i>Bedbug</i>					
<i>Oak tree</i>					
<i>Crab</i>					
<i>American citizen</i>					

Questions. 1. Which of the processes or activities named are essential to life? Mark with A.

2. Which of the organs mentioned are essential to life? Mark with X.

EXERCISE 99

Nutrition is a process going on in every living cell, and many of the activities of a many-celled organism are related to nutrition. In the spaces of the table tell briefly what organs and processes of the organism as a whole carry forward nutrition, and also what structures and processes in the individual cell mentioned.

NUTRITION STRUCTURES AND PROCESSES

<i>The frog as a whole</i>	<i>The potato plant</i>
<i>A cell in the muscle of the frog's leg</i>	<i>A cell in the bark of the potato's tuber</i>

EXERCISE 100

Respiration is related primarily to the release of energy in protoplasm. It is carried on by every living cell. In many-celled organisms we find a variety of structures and processes related to respiration. Respiration involves an *intake* and an *output* of gases. In the spaces below tell briefly what structures and processes are involved in the respiration of the named organism and in the respiration of the individual cells mentioned.

STRUCTURES AND PROCESSES INVOLVED IN RESPIRATION

	INTAKE	OUTPUT
<i>Grasshopper</i>		
<i>Cell in a digestive gland of a grasshopper</i>		
<i>Willow tree</i>		
<i>Cambium cell in the stem of a willow</i>		

EXERCISE 101

Many of the substances resulting from the metabolism in a cell (the chemical changes going on in protoplasm) are injurious to protoplasm and must be removed if the cell is to continue living. In many-celled organisms various structures and processes are related to excretion.

In the table below enter in the appropriate spaces the names of the materials thrown out and the structures and processes involved in excretion.

EXCRETION FROM LIVING CELLS AND FROM ORGANISMS

	EXCRETED SUBSTANCES	EXCRETING STRUCTURES AND PROCESSES
<i>Human being</i>		
<i>Cell of gray matter in spinal cord</i>		
<i>Apple tree</i>		
<i>Palisade cell of leaf</i>		

EXERCISE 102

In some ways the nutrition processes in all living things are very much alike ; but every class of plants or animals, and in many cases every species, has its own peculiarities. In the following table describe briefly the resemblances in the matter of nutrition, and also the distinctive structures and processes, of each organism named.

RESEMBLANCES AND DIFFERENCES REGARDING NUTRITION OF VARIOUS ORGANISMS

	RESEMBLANCES	DISTINCTIVE STRUCTURES AND PROCESSES
<i>Paramecium</i>		
<i>Bean plant</i>		
<i>Clam</i>		
<i>Butterfly (larva)</i>		
<i>Butterfly (adult)</i>		
<i>Man</i>		

EXERCISE 103

Inspiration of oxygen and expiration of carbon dioxid take place in practically every plant and every animal, but every class of organisms shows some distinctive structures and processes in relation to breathing.

In the table below indicate briefly what the organisms named have in common (with regard to respiration) and in what processes or structures their respiration differs.

RESEMBLANCES AND DIFFERENCES AMONG ORGANISMS WITH RESPECT TO RESPIRATION

	RESEMBLANCES	DISTINCTIVE STRUCTURES AND PROCESSES
<i>Spirogyra</i>		
<i>Potato beetle</i>		
<i>Perch</i>		
<i>Frog</i>		
<i>Robin</i>		

EXERCISE 104

Every living cell and every living organism must get out of its protoplasm the injurious by-products of metabolism ; but different organisms accomplish this result in different ways.

In the following table indicate in what ways the plants and animals named get rid of their wastes, pointing out first their resemblances and then their distinctive structures and activities.

RESEMBLANCES AND DIFFERENCES OF VARIOUS ORGANISMS WITH RESPECT TO EXCRETION

	RESEMBLANCES	DISTINCTIVE STRUCTURES AND PROCESSES
<i>Diphtheria bacillus</i>		
<i>Earthworm</i>		
<i>Frog</i>		

- Questions. 1. In what respects does excretion resemble respiration ?
2. In what respects do these two processes differ ?
3. In what ways can wastes be made harmless to the organism besides expelling them from the system ?

EXERCISE 105

While all protoplasm can contract, not all organisms can move about. Different types of plants and animals show distinctive modes of locomotion and distinctive ways of moving in relation to getting food and in relation to escape from enemies. Organs that behave in the same way with relation to the organism's living are said to be *analogous*, even if they are really different kinds of organs — for example, the wings of insects, of birds, and of bats. Organs that have the same kind of origin and structure are said to be *homologous*, even if they are used differently — for example, the claws of a cat and the toes of an elephant, the balancers of a house fly and the hind wings of a moth.

In the table below indicate the organs of locomotion distinctive of each type of organism mentioned, and tell in what medium it works and how it is used.

TYPES OF LOCOMOTIVE ORGANS AND ACTIVITIES

NAME OF TYPE	NAME OF ORGANS	HOW USED	MEDIUM
<i>Ameba</i>			
<i>Typhoid bacillus</i>			
<i>Worm</i> ----- (Name)			
<i>Mollusk</i> ----- (Name)			
<i>Insect</i> ----- (Name)			
<i>Crustacean</i> ----- (Name)			
<i>Fish</i> ----- (Name)			
<i>Toad (larva)</i>			
<i>Toad (adult)</i>			
<i>Alligator</i>			
<i>Ostrich</i>			
<i>Monkey</i>			

EXERCISE 105 (Continued)

Go over the list of organs named and place the letter *a* after the first one and after all the others that are *homologous* with it; then place the letter *b* after the first one not yet marked and after each one that is homologous with it; then mark a third group with the letter *c*; and so on until all are checked off.

Go over the list again and mark with a capital *A* the first one and all that are *analogous* with it; then mark with a letter *B* all that are analogous with each other but not with the first group; and so on.

Questions. 1. What are the greatest differences that you have observed between organs that are homologous?

2. What are the most diverse organs that you have observed as having a similar function?

3. What is suggested by a study of analogies and homologies concerning the *plasticity* of protoplasm?

EXERCISE 106

All protoplasm is irritable, but not all organisms have special sense organs. While the reactions of organisms to stimulation often bring them into more favorable positions with relation to the environment, not every sensation or every response is necessarily of benefit to the organism.

In the following table indicate the responses of the organisms named to the different kinds of stimulation, and the value of these responses to them.

	STIMULI					
	Touch		Chemical		Light	
	Reaction	Value of Reaction	Reaction	Value of Reaction	Reaction	Value of Reaction
<i>Ameba</i>						
<i>Crayfish</i>						
<i>Night moth</i>						
<i>Man</i>						

Question. What are some plant and animal reactions that are injurious to the organisms?

EXERCISE 107

While all living things must have the same nutrients (proteins, fuels, etc.), they do not all get their food from the same sources. And while all organisms must take into themselves certain materials from their environment, they do not all seize and ingest their food in the same way.

In the following table indicate the sources, the organs, and the modes of ingestion that are characteristic of the feeding of the organisms named.

FOOD-GETTING AND FOOD-INGESTION OF VARIOUS TYPES OF ORGANISMS

TYPE OF ORGANISM	NATURE OF FOOD	ORGANS	PROCESSES
<i>Ameba</i>			
<i>Maple tree</i>			
<i>Sponge</i>			
<i>Tapeworm</i>			
<i>Ground beetle</i>			
<i>Mosquito</i>			
<i>Snake</i>			
<i>Barn swallow</i>			
<i>Cat</i>			

EXERCISE 108

The exchange of material between an organism and its environment, in nutrition, in respiration, and in excretion, takes place through the general body surface or through special surfaces. In many organisms the total amount of metabolism therefore depends directly upon the total amount of surface that can be exposed.

Problem. Does not the amount of surface of a body vary directly with the size of the body?

What to use. A number of cubical blocks of the same size, wooden or clay.

What to do. Since the blocks are all the same size, we may count the edge of a block as the unit of length (for example, 1 inch, 1 centimeter), one face of a cube as the unit of area (for example, 1 square inch, 1 square centimeter), and so on. Build up sets of blocks having one, two, three, etc. inches as a base, with the same width and height, and note the total amount of exposed surface each such cubical pile has. The cubical measure may be taken as proportional to the mass or weight of the body represented by such a pile. Note the relation between the surface of a cube and its mass.

Record. In the table enter the observed or calculated *surface* and the volume of mass for a cube of each dimension.

LENGTH IN INCHES	AREA IN SQUARE INCHES	VOLUME IN CUBIC INCHES	LENGTH IN INCHES	AREA IN SQUARE INCHES	VOLUME IN CUBIC INCHES
1			6		
2			7		
3			8		
4			9		
5			10		

- Questions.**
1. What effect upon its volume has the doubling of the dimensions of an object?
 2. What effect upon its surface has the doubling of the dimensions of an object?
 3. Does the ratio of surface to volume remain constant? Why?
 4. How would you arrange eight blocks to get the largest amount of surface exposed?
 5. How would you arrange eight blocks to get the smallest amount of surface exposed?
 6. What is the effect of growth upon the relative amount of absorbing surface?
 7. What kinds of organisms are capable of indefinite growth?
 8. What are some of the ways in which the structure of an absorbing or discharging surface makes for a large area?

EXERCISE 109—DEMONSTRATION

When part of a plant or of an animal is cut off, in some cases the surface merely heals up, while in other cases the whole of the missing part is regrown.

Problem. How much can be regrown if half of a worm is cut off?

What to use. A live earthworm or a live *Planaria* (flatworm); sharp knife or scissors.

What to do. Cut the animal into two close to the middle, and return to earth or water for further observation.

Record. Describe the response of the animal to the section, and the changes to be noted from time to time—say at intervals of two days. Make drawings showing what happened to each part, as well as the appearance of the worm before the operation.

Questions. 1. What practical use can be made of the fact that organisms can regrow removed parts?
2. What is the difference between the regeneration of roots on a slip or cutting and the formation of a new plant from a bulb or tuber?

EXERCISE 110

Problem. What are the early stages in the development of a backboned animal from the egg?

What to use. Fresh frog eggs or fish eggs¹; magnifiers; microscope.

What to do. Watch the eggs, with unaided eye, with magnifying glass, and with microscope, to note changes that take place from time to time.

Record. Make drawings to show the stages observed.

Questions. 1. How does the single cell become a many-celled body?

2. At what point do the cells appear to be of two or more different kinds?

¹ If live eggs are not available, make study from models or from charts.

EXERCISE 111

Problem. How do eggs of mosquitoes change into adults?

What to use. Glass jar or tumbler; cheesecloth; large magnifying glass.

What to do. Get some fresh pond water; have glass about two-thirds full. Leave water in glass exposed out of doors overnight; in the morning examine the surface of the water for mosquito eggs. If any are found, cover glass with cheesecloth. Then study with magnifying glass from day to day to note changes that take place.

Record. Make drawings to illustrate the changes noted. Describe movements of larvæ etc.

Questions. 1. How many eggs were there? How many hatched out?

2. How can you tell whether the mosquitoes that hatch out in the glass are infected with malaria or some other disease parasite?

EXERCISE 112

The conditions for development and the conditions for growth are usually but not always the same for a given plant or animal. Part of the life cycle may be passed in the winter and another part in the summer, so that the most favorable temperature may not be the same for growth as for later changes.

Problem. What is the effect of high temperature on the development of an insect that normally spends parts of its resting stage in the cold?

What to use. A number of cocoons or pupæ of some common insect, gathered in the fall.

What to do. Place some of the cocoons in a battery jar in the classroom; leave others in a jar or box out of doors. Watch from time to time to anticipate an early emergence of the adult. Date the insects as they come out. When the last of the brood has emerged, make comparisons as to size, patterns, etc.

Record. Describe the results and your conclusions.

Questions. 1. How can you tell that the inside of the cocoons kept indoors was warmer than in the case of those that remained out of doors?

2. Is the difference in temperature between the indoor pupæ and the outdoor pupæ the same as the difference between the classroom and the out of doors? How do you know?

3. What advantages or disadvantages are indicated by any differences in development that you discovered?

EXERCISE 113

The spores of various plants are usually so small that single ones cannot be seen without a microscope. They are thus blown about in the dust.

Problem. How widespread are the spores of common spore-producing plants?

What to use. Pieces of moist bread or diluted sirups or fruit juices (a teaspoonful to a pint of water), to catch the spores; moist chambers (consisting of a tumbler inverted over several thicknesses of moist filter paper or blotter), to hold the bread; test tubes, closed with cotton plugs, to hold the sirups.

What to do. Expose pieces of bread or tubes of sirup in various situations overnight; cover and leave in a dark cupboard or under a box, at ordinary temperature or warmer. Examine at intervals of twenty-four hours and note numbers and kinds of growths.

Record. Describe the results from different sources and make up your mind where different kinds of spores are likely to be most abundant. If it is possible to examine with a microscope, add drawings to record.

Questions. 1. Do all kinds of dust contain spores?

2. What kinds of growth are most likely to come from the dust in a closely populated neighborhood?

3. What kinds of spores are most likely to be found in the woods?

EXERCISE 114

Problem. How does conjugation take place in a simple plant?

What to use. Microscope; slides and cover glasses; pond scum — *Spirogyra*.

What to do. Mount *Spirogyra* and examine with microscope, to learn the structure of the cell, the nucleus, and the chlorophyl band. Bits of *Spirogyra* from the bottom of the jar, when they begin to change color, should be examined for conjugation stages; these will be recognized by the fact that two threads lie close together, with outgrowths reaching across, forming a ladder-shaped arrangement. Note any changes going on in any part of the cell.

Record. With the aid of diagrams describe the stages found and the end result.

- Questions.**
1. Are all the empty cells in one thread, or are there some empty cells in each thread?
 2. Are the cells of one thread (before conjugation) distinguishable from those of the other thread — in size, in structure, in color, or in any other way?
 3. How does the zygote resulting from conjugation differ from a spore?

EXERCISE 115

Problem. How do spores look, and how do they start new plants?

What to use. Microscope; slides; cover glasses; dissecting needle; water; sugar; spores of various kinds, including pollen grains from flowers.

What to do. Place a few spores in a drop of very dilute sirup on a glass slide by touching needle to an anther and then touching it to the drop of sirup. Do the same with spore masses of mold growing on bread, fruit rinds, or cheese. Leave in moist chamber overnight. Cover, and examine with microscope.

Record. By means of drawings and words show the appearance of spores used and of the beginning of new plants.

- Questions.** 1. In what ways do growths from pollen grains resemble growths from other spores?
2. How do growths from pollen grains differ from other spore products?

The flower is the seed-producing part of a plant, although the part that we usually notice is not the one that makes seeds.

Problem. What are the organs of a flower, and how do they make seeds?

What to use. A complete,¹ regular,² and perfect³ flower, such as the tulip or wild rose; a magnifying glass.

What to do. Examine the parts of the flower and their arrangement.

NOTE 1. The parts of the flower are arranged in circles, or rings, and are all attached to an enlargement of the end of the stalk, called the *receptacle*.

NOTE 2. The outer circle is called the *calyx*; and its parts, which may be quite distinct or more or less fused together, are called *sepals*.

NOTE 3. The second circle (from the outside) is called the *corolla*; and its parts, which may be distinct or united, are *petals*.

NOTE 4. The calyx and corolla together constitute the floral envelope and are not essential to the making of seeds. In many kinds of plants the flower has no envelope.

NOTE 5. The central organ is the *pistil* and may consist of one or several *carpels* (which can usually be recognized by ridges running lengthwise). The main parts of the pistil are the *ovary*, or seed-bearing chamber, usually the thickest part and at the base; the *stigma*, or tip; and the part connecting stigma with ovary, or the *style*.

NOTE 6. The stalklike or threadlike structures with little knobs, surrounding the pistil, are the *stamens*. The stalk is called the *filament*, and the pollen-case at the top is the *anther*.

Record. Make diagrams to illustrate the structure of the whole flower and the arrangement of the parts; label every structure named in the notes.

Make a cross section of the ovary, and draw, showing the separate carpels and the area carrying the ovules, which are to become the seeds.

NOTE 7. The surface to which ovules are attached is called the placenta.

¹ A complete flower is one that has a floral envelope as well as the seed-making organs.

² A regular flower is one in which the organs of each circle are all alike as to form.

³ A perfect flower is one that has both stamens and pistils.

EXERCISE 116 (Continued)

- Questions.** 1. How many sepals are there? Are they separate or joined?
2. How many petals are there? Are they separate or joined?
3. How are the sepals placed with relation to the petals?
4. How many stamens are there? Are they separate or joined?
5. How are the stamens placed with relation to the petals?
6. How is the anther attached to the filament?
7. What is there about the anther that would permit the pollen to get out?
8. What is there about the stigma that would permit pollen spores to cling to it?
9. How many distinct seed chambers are there in the ovary?
10. Are the seed chambers completely partitioned from each other?
11. How many rows of ovules are there?
12. Which do you consider the essential organs of the flower? Why?

NOTE 8. The relation of pollen to seed-making cannot be inferred from a study of the flower's structure, but will be studied later.

EXERCISE 117

Problem. In what ways may flowers differ from each other and still carry on the work of seed-making?

What to use. Flowers of various kinds; magnifying glass; dissecting needles.

What to do. Examine one flower at a time and note in what ways it resembles and in what ways it differs from the first flower studied. Check up the sizes and shapes of the several organs, their markings, their numbers, and their arrangement.

Record. Describe, following the questions in Exercise 116 and using diagrams. Enter the name of each species studied.

NOTE. In some species of plants the flowers contain peculiar or unusual structures not mentioned in the study. Make a record, with drawings if possible, of any such found.

EXERCISE 118

Seeds develop from ovules, but only, as a rule, after protoplasm from the pollen reaches and fuses with protoplasm inside the ovule.

Problem. How does the protoplasm from the pollen reach the inside of the ovule?

What to use. Some live flowers; slides; dilute sirup (sugar in water, about three per cent); moist chamber; section cutter or razor; prepared sections of ovules.

What to do. 1. Get some pollen from the anthers of the flower to sprout in a drop of sirup on a glass slide in a moist chamber (see Exercise 115); examine with the microscope.

NOTE. The nucleus near the end of the pollen tube is the male, or *sperm*, nucleus, which is to unite with protoplasm in the ovule.

2. Examine the surface of the stigma to see (a) how pollen grains can find lodgment on it, and (b) what would make pollen grains sprout there, forming pollen tubes.

NOTE. The style is usually either hollow through the middle or made up of loose tissue through which a pollen tube readily grows.

3. Examine several ovules with low power of the microscope, to find the micropyle (see Exercise 30) through which the pollen tube may enter the ovule.

4. Examine sections of ovule and note the large cell on the inside — the embryo sac, inside of which the new plant, or embryo, is to develop.

NOTE. The original nucleus of the embryo sac divides several times. One of the resulting nuclei is the female, or *egg*, nucleus, and unites with the sperm from the pollen tube.

Record. Draw and describe the structures studied.

Questions. 1. How does the protoplasm of the pollen spore reach the ovule?

2. How does the sperm from the pollen tube get to the embryo sac?

3. What is likely to become of the ovule as the embryo ripens?

4. How is the developing embryo nourished?

EXERCISE 119

The transfer of pollen from the anther of one flower to the stigma of another is in most cases brought about either by the wind or by insects.

Problem. What is there about flowers that makes possible the distribution of pollen by the wind?

What to use. A magnifying glass and a pair of sharp eyes.

What to do. Examine the pollen, the stigmas, and the envelopes of many different wild and cultivated plants in the field, and note the probability of the pollen's being easily blown from the anther, being easily carried by the wind, and being readily caught by the stigmas. Compare various kinds of flowers to note differences that are likely to be significant in this connection.

Record. Make a list of plants that you consider to be probably wind-pollinated, and describe the characteristics that lead you to your conclusions.

NAMES OF PLANTS	CHARACTER OF POLLEN	CHARACTER OF STIGMA	CHARACTER OF FLORAL ENVELOPE

EXERCISE 120

Problem. What is there about flowers that makes possible the distribution of their pollen by insects?

What to use. As in previous exercise.

What to do. Examine the stamens, pollen, stigmas, and envelope of many different wild and cultivated flowers, looking out especially for flowers around which insects are hovering. Note the relative position of the anther and the stigma and the character of the pollen that would make distribution by insects probable. Note what there is about the structure of the flower as a whole that would make the visits of insects likely.

Record. Make a list of plants that you think are probably insect-pollinated, illustrate by drawings, and describe the characteristics that lead to your conclusions.

NAMES OF PLANTS	CHARACTER OF POLLEN	POSITION OF STIGMA	CHARACTER OF FLORAL ENVELOPE	PROBABLE INSECT VISITOR

Questions. 1. What practical use is made of the fact that insects make their food stores out of flower nectar?

2. What plants secrete nectar without getting their pollen transferred by insects?

3. Can you find insects visiting flowers without serving as pollen carriers?

4. What plants with odorous and conspicuous flowers are pollinated without the aid of insects?

EXERCISE 121

When the ovary ripens into a seed-carrier, the ovary and certain other parts of the flower may grow together and form the fruit.

Problem. What structures besides the ovary are represented in the fruit?

What to use. Several different kinds of fruits, including fleshy fruits, pods, grains, berries, etc.; knife; magnifying glass.

What to do. Examine the fruits carefully (first externally, then in cross and longitudinal sections), to discover how much originated from the ovary or other part of the pistil and what remains of the receptacle, of the calyx, etc.

NOTE. In the composite family (to which the sunflowers belong), as well as in some other families of plants, there is sometimes formed a group of leaflike scales at the base of the flower cluster. This *involucre* in many cases becomes fused into a more or less adherent part of the fruit.

Record. Make a list of the fruits studied, and opposite each tell (1) what parts of the plant have become part of the fruit, and (2) what functions are probably performed by each part.

NAME OF FRUIT	PARTS OF PLANT OR OTHER STRUCTURES PRESENT IN FRUIT	FUNCTIONS OF THE DIFFERENT PARTS

Questions. 1. What changes take place in the ripening of a fruit that are of value to the plant or to the species?

2. What changes take place in the ripening of fruits that make certain ones of value to man?

3. What are some of the uses to which we put fruits?

4. What are some important differences between wild and domesticated fruits?

EXERCISE 122

From the viewpoint of a race of plants the fruit is of value (1) as a protection to the young plant until it can be safely launched away from "home," and (2) as an aid in distributing the seeds over as wide an area as possible. Since plants are not, as a rule, organisms that are capable of independent locomotion, they must depend upon outside moving agencies to transport them.

Problem. In what ways are fruits and seeds adapted to wide distribution?

What to use. Many different kinds of fruits and seeds in the field, woods, or garden ; some to study in detail in the laboratory.

What to do. Examine the fruits and seeds to see what there is about them that fits them to a wide distribution. Consider what agencies in their environment might be available as aids in distribution, and what processes of the parent plants might be of service.

Record. Make a list of distinct types of fruits or seeds, illustrating different modes of distribution, and describe their modes of dissemination.

	NAMES OF PLANTS	AGENCIES AIDING IN DISTRIBUTION	STRUCTURES AND OTHER CHARACTERS AND THEIR RELATION TO THE DISTRIBUTING AGENCIES
Example	<i>Cocklebur</i>	<i>Moving animals</i>	<i>Spines with hooked ends, clinging to fur</i>
1			
2			
3			
4			
5			

Questions. 1. What advantage is it to a plant to produce seeds?

2. What advantage is it to a plant to scatter its seeds far from its own base?

3. Of what advantage to the species is wide distribution?

EXERCISE 123

In all except the lowest families of plants there are two modes of reproduction and two distinct generations, each reproducing in its own way. One generation, reproducing by means of sperms and eggs, is called the *sexual* generation; the other, reproducing by means of spores, is called the sexless, or *asexual*, generation.

Problem. What is the life history of a plant having alternation of sexual and asexual generations?

What to use. Fresh or dried moss of some large variety, with the "fruit" stalks, complete; some without the fruits; microscope with slides etc.; magnifying glass; section cutter; prepared microscopic slides.

What to do. 1. If dry material is used, it should be soaked up in water. Examine the plant without fruit and note its main parts and the arrangement and character of the "leaves." This is the sexual generation. Note the rosette of leaves at the top. Examine several specimens with the glass to find structural differences. Make longitudinal sections through the tips of several specimens and examine with the microscope. Compare your sections with the prepared ones.

NOTE 1. It is possible to find, among the hairlike growths within some of the rosettes, flask-shaped organs, the *archegonia*, each containing a large egg cell in the basal portion; and in other rosettes, club-shaped structures, the *antheridia*, each of which produces a large number of sperm cells.

2. Examine some of the fruiting specimens and note the stalk and the spore capsule on top, the hood over the capsule, the lid, and the structure of the mouth after the lid is removed. This is the asexual generation. Study with the magnifying glass all the structures named. Make cross and longitudinal sections of the spore case and study with the microscope. Compare your sections with the prepared ones.

NOTE 2. Sperm cells swim about by means of *cilia*, and some find their way down the neck of an archegonium, where one unites with the egg cell. The fertilized egg cell begins at once to develop into a spore-bearing individual, absorbing practically all its food from the parent plant—the female sexual individual. The hood on top of the spore case is the upper part of the archegonium, which continues to grow for a while after fertilization takes place.

NOTE 3. The spore-bearing (asexual) individual is called the *sporophyte*. The gamete-bearing (sexual) individuals, bearing the sperm or eggs, are called the *gametophytes*.

EXERCISE 123 (Continued)

Record. Make enlarged drawings to show the following structures :

1. Gametophyte as a whole, stalk, " roots," " leaves."
2. Longitudinal section of rosette showing archegonia.
3. Longitudinal section showing antheridia.
4. Sporophyte growing out of gametophyte, general view.
5. Enlarged view of spore capsule, with hood and lid separated.
6. Longitudinal section of spore capsule.
7. Microscopic view of spores.

NOTE 4. In the mosses, a sporophyte always develops from a fertilized egg, and a gametophyte always develops from a spore.

Questions. 1. What are the most striking structural differences between the sporophyte and the gametophyte in the moss?

2. Which generation is the better food producer? Why?
3. Which generation contributes more to a wide distribution of the species? How?
4. What conditions must be necessary for fertilization?
5. In what sense is the gametophyte dependent upon the sporophyte?
6. In what sense is the sporophyte dependent upon the gametophyte?
7. Which generation could more readily live an independent life if it were once started on its way? Why?

EXERCISE 124

In the highest plants the gametophyte is always parasitic on the sporophyte, whereas in the lower plants (mosses) the sporophyte is parasitic on the gametophyte.

Problem. Are there any plants in which the two generations are about equally self-sustaining?

What to use. Fern plants, complete, with fruiting dots; prothalli of fern; magnifying glass; microscope with slides etc.

What to do. 1. Examine the fern plant and note structure of underground stem, roots, leaf, and spore areas on underside or at edge of frond. Examine spore cases and spores under microscope, noting especially the part of the spore case that is related to the scattering of the spores.

NOTE 1. The familiar stage of the fern plant is the sporophyte. It develops from a fertilized egg and bears spores.

2. Examine prothalli under the microscope as well as with magnifying glass. Study under surface as well as upper. Note rhizoids, like root hairs; archegonia near the front edge and antheridia near the hind edge.

NOTE 2. The prothallus is the gametophyte; it develops from a spore. Eggs and sperms are borne on one individual. After fertilization the egg develops into a sporophyte.

Record. Make drawings and label to show the following stages and structures:

1. The sporophyte as a whole, with characteristic leaves, rootstock (underground stem), and absorbing organs.

2. The fruiting dots, or masses of spore cases: microscopic view of (a) spore case entire; (b) spore case broken; (c) spores.

3. The gametophyte (upper surface), enlarged.

4. Lower surface of gametophyte, under microscope: (a) rhizoids; (b) archegonia; (c) antheridia; and, if possible, (d) egg and sperm cells.

EXERCISE 124 (Continued)

Questions. 1. Which do you consider the more highly developed organism, the sporophyte or the gametophyte? Why?

2. Could the sporophyte perpetuate itself without the gametophyte? Why?

3. Could the gametophyte perpetuate itself without the sporophyte? Why?

4. In what sense is the sporophyte dependent upon the gametophyte?

5. In what sense is the gametophyte dependent upon the sporophyte?

EXERCISE 125

In the following table, list, in the appropriate spaces, the organs or structures, tissues, etc. that are distinctive of each type of plant—that is, the structures present in one generation that are not to be found in the alternate generation. For example, in the sporophyte of the seed-bearing plants there are flowers, while there are none in the gametophyte.

	PRESENT IN SPOROPHYTE BUT NOT IN GAMETOPHYTE	PRESENT IN GAMETOPHYTE BUT NOT IN SPOROPHYTE
<i>Of mosses</i>		
<i>Of ferns</i>		
<i>Of seed plants</i>		

- Questions.** 1. How does the mode of life of a moss sporophyte compare with that of a fern sporophyte?
 2. How does the mode of life of a moss gametophyte compare with that of a violet gametophyte?
 3. What is there in a moss plant to correspond to a flower?
 4. How many kinds of gametophytes are there in a moss? in a fern? in an apple?
 5. What is there in a tomato plant to correspond to the fruit dots of a fern?

EXERCISE 126

Reproduction by means of gametes and reproduction by means of spores seem to have led in most families of plants to the evolution of two distinct generations. In almost all the familiar species of plants the spore-bearing generation has become not only more conspicuous in size but more highly specialized in the number and variety of organs and tissues. On the other hand, the gamete-bearing generation has tended to become reduced to a microscopic body, simple in structure and parasitic in habit.

In the following table sketch and describe briefly the various stages in the life history of the types named, emphasizing the distinctive traits in each case.

STAGES AND ORGANS	A MOSS	A FERN	A SPERMATOPHYTE
<i>Fertilized egg</i>			
<i>Sporophyte</i>			
<i>Spore case</i>			
<i>Spore</i>			
<i>Gametophyte</i>			
<i>Gamete-bearers (male and female)</i>			
<i>Gametes</i>			

EXERCISE 127

In all except a few species of small animals, reproduction is brought about by the fusion of a sperm cell with an egg cell. But there is great variation in the number of individuals produced and in the relation between parent and offspring after the discharge of the gametes.

From prepared specimens, models, and charts gather the information needed for completing the following table, giving the name of the type studied in each case :

	NUMBER OF OFFSPRING	WHERE FERTILIZATION TAKES PLACE	WHERE DEVELOPMENT TAKES PLACE	WHAT PARENTS SUPPLY FOR DEVELOPING EMBRYO
FISH (Name)				
BIRD (Name)				
MAMMAL (Name)				

Questions. 1. What relation is there between the number of gametes discharged and the number of fertilized eggs that reach maturity?

2. What connection is there between the number of individuals produced and the amount of aid each gets from the parents?

3. Of what does parental care consist? Of what value is it to (a) the individual and to (b) the species?

4. What connection is there between the amount of care the individual receives and his chances of maturing?

5. How far is your last statement true of human beings?

EXERCISE 128

Problem. What is the relation of light to the growth of living things?

What to use. Sterilized petri dishes with culture media ; black paper.

What to do. Expose two petri dishes to infection by dust from the air. Cut a hole of a distinctive form in a piece of black paper. Cover one dish with the perforated paper and one with whole paper. Expose both to bright sunshine at room temperature or warmer for twenty-four hours.

Record. Examine petri dishes. Make diagram showing numbers and distribution of colonies in both. Tell what effect the sunshine had on the growth of the bacteria.

- Questions.**
1. What practical use can be made of the fact brought out by this experiment?
 2. How do these results harmonize with what we know about the need that plants have of sunlight?
 3. What is there in your experience with animals that corresponds to these results?

EXERCISE 129

Many of the activities of living things have to do with matters that interfere with life. Conditions vary from one region to another and from season to season; protoplasm must adjust itself to these variations in space and time. The structures and habits of related animals and plants are accordingly different in different regions, and the appearance and habits of one species vary from season to season.

Problem. What are some of the differences between the summer and the winter conditions of organisms?

What to do. In the following tables indicate briefly what is distinctive during the extreme seasons for five types of plants and for five types of animals.

PLANTS

	NAME OF ORGANISM	WHAT IT HAS OR DOES	
		In summer but not in winter	In winter but not in summer
Example	<i>Spirogyra</i>	<i>Grows ; reproduces ; has chlorophyll bands ; forms zygotes</i>	<i>Resting stage ; encysted cells</i>
1			
2			
3			
4			
5			

ANIMALS

	NAME OF ORGANISM	WHAT IT HAS OR DOES	
		In summer but not in winter	In winter but not in summer
Example	<i>Mosquito</i>	<i>Flies about ; reproduces ; adult female and wigglers feed</i>	<i>Adults only ; sluggish, resting in dark corners</i>
1			
2			
3			
4			
5			

EXERCISE 129 (Continued)

- Questions.** 1. What differences besides those of temperature are there between summer and winter?
2. How do these other differences influence the behavior of plants?
 3. How do these other differences influence the behavior of animals?
 4. How does the season's effect upon one group of organisms influence other organisms?
 5. What practical use is made of the fact that certain organisms are inactive at low temperatures?
 6. How does low temperature probably reduce the activity of protoplasm?
 7. How does high temperature probably reduce the activity of living matter?
 8. How does shortage of water influence the activity of protoplasm?
 9. What practical use can be made of the fact that a shortage of water reduces protoplasm activity?
 10. What practical use can be made of the fact that organisms change their habits with the seasons?

EXERCISE 130

The rain is said to fall alike on the just and the unjust ; but one with an umbrella may save her bonnet. A passenger boat sinks and throws the wise and the foolish into the water ; if near shore, a few may swim and save themselves.

Give five examples of situations in which some plants or animals are successful, while others fail, and point out what it is that makes the difference.

	DESTRUCTIVE SITUATION	SOURCE OF ADVANTAGE
Example	<i>A severe winter ; many birds perish</i>	<i>Better feathers save some</i>
1		
2		
3		
4		
5		

Give five examples of situations in which plants or animals are destroyed without discrimination.

Example	<i>A forest fire destroys plants and animals without discrimination</i>
1	
2	
3	
4	
5	

Questions. 1. In the survivals of the first set of examples, do the plants or the animals struggle with one another or with outside conditions ?

2. What qualities would help plants or animals to escape or to survive a forest fire ? a severe windstorm ? a famine ? a drought ?

EXERCISE 131

Problem. What is the influence of light and color on pigmentation?

What to use. A living fence lizard, chameleon, toad, snake, or fish. Papers of various colors and shades.

What to do. By means of the papers change the background of the animal in various ways, giving several minutes for each possible reaction. Note any changes that take place in the appearance of the animal.

Questions. 1. Does the animal respond more readily to a change of shade (illumination) or to a change of color?

2. Does it respond more readily to an increase or to a decrease in illumination?
3. Can different parts of the body respond in opposite ways?
4. Do the changes depend upon the animal's *seeing* the colors?
5. How does temperature affect the color of the skin?
6. How does temperature affect the response of the animal to changes in the background?

EXERCISE 132

Study of protective movements and activities.

What to use. Any convenient live animal in an aquarium, cage, or vivarium.

What to do. Expose the animal to various kinds of stimulation or disturbance. Record its reaction.

Contact stimulation. Touch gently with a straw or light rod in different parts of the body.

1. Does the animal move toward or away from point of contact?
2. Is this response the same in all parts of the body?
3. Which is more sensitive to contact, the anterior (forward) or posterior (hind) end?

NOTE. In *radially* symmetrical animals, such as starfish, sea anemones, and others, we cannot distinguish anterior and posterior regions, but we may speak of the oral (mouth) region or surface and the aboral (away-from-mouth) region.

4. Which is more sensitive to contact, the dorsal (back, or shoulder) side or the ventral (under, or belly) side?

5. Are the right and the left side equally sensitive?

6. What does the animal do on coming in contact with a solid in the course of its movements?

Sight stimulation. Bring your hand, a stick, or a piece of paper toward the animal, from different directions and at different speeds.

1. What effect does the sight of an object produce in the behavior of the animal?
2. At what distance does an approaching object set up responses in the animal?
3. How does the distance vary with the *direction* from which the animal is approached?
4. What kind of reaction does a reduction of illumination (shadow) produce?
5. What kind of reaction does an increase of illumination produce?
6. How does the response to rapidly moving objects differ from that to slowly moving objects?

EXERCISE 132 (Continued)

Sound stimulation. Try low sounds of various kinds ; scratch or rub the table with the jar ; agitate the water gently.

1. How can you tell that your animal is sensitive to sound ?
2. Is it sensitive to vibrations in solids or liquids, other than sounds ?

Questions. 1. What advantage do you think the animal gets from reacting as it does to various disturbances ?

2. In a given situation, does the animal seem to choose what to do ?
3. Are there any movements that could be considered offensive rather than, or as well as, defensive ?

Movements of plants. If a sensitive plant is available, study the *location*, the *kind*, and the *intensity* of disturbance necessary to set up the characteristic reaction.

Describe the plant's movements.

Note how much time it takes to recover the open position.

Questions. 1. Does *illumination* affect the sensitiveness ?

2. What benefit does the plant seem to derive from the reaction to this disturbance ?

EXERCISE 133

In animals that have two or more similar parts (or pairs of structures) arranged from front to rear, such as vertebræ, rings of a worm, paired appendages, etc., these parts are considered to be *homologous*, or of identical origin. Among backboned animals and among arthropods (insects, crustaceans, spiders, etc.), where the appendages are numerous, it is possible to find species that show one or more special modifications of structure related to *protection*.

In some suitable specimen (for example, grasshopper, crayfish, crab, beetle, frog, cat, etc.) study the homologous structures, to find in what ways any of them show adaptation to protection of the individual.

Record your findings, using diagrams to bring out the differences between the protecting structures and the homologous structures that are not protecting.

EXERCISE 134

Find and draw an object showing the results of the activities of some animal, which bring about the protection of the animal itself, or of the offspring, against either (a) unfavorable conditions or (b) its enemies.

- Questions.** 1. How can you tell that the activities represented are really protective?
2. What human activities correspond to those represented in your specimen?

EXERCISE 135

Problem. How does the natural fall of leaves differ from the breaking off of leaves?

What to use. Twigs of deciduous trees bearing leaves and showing old leaf scars ; magnifying glasses ; microscope ; prepared slide.

What to do. Study several of the old leaf scars. Break off one or two leaves near the base of the petiole (leafstalk) and study the scars left. Study sections through base of petiole with microscope.

Record. Make a large drawing of a typical natural scar and of one resulting from tearing off the leaf. Make a drawing of section through the scission (splitting) layer as seen with the microscope.

Questions. 1. What region of the petiole is most easily broken?

2. What marks the region that separates when the leaf falls?

3. How does the surface of the natural scar differ from that of the artificial scar?

EXERCISE 136

The forest is said to conserve the water on the hillside not only through the shielding of the soil against the downpour and against evaporation, and through the action of the roots, but also through the formation of the *mulch*, consisting of decaying leaves and other organic matter.

Problem. What is the relation of the mulch to the removal of rain water?

What to use. Two funnels of the same size; two test tubes or bottles of the same size; sand; forest mulch; absorbent cotton; water; supports for the funnels.

What to do. Plug the funnels loosely with cotton; fill to within an inch of the top with sand; cover surface in one funnel with mulch. Place a bottle or test tube under each funnel and pour the same quantity of water on top of each.

Record. After a few minutes note the amount of water that has come through the soil in the two funnels; what does the result show regarding the relation of the mulch to the water flow?

- Questions.**
1. How would you determine the drainage quality of different kinds of soil?
 2. Where would mulch be produced in the largest quantity?
 3. In what way would a mulch be of value on a farm or in a garden?
 4. Why cannot the natural soil cover serve as a mulch in the cultivated fields?
 5. In what rivers has the flow of water been affected by the cutting down of forests?

EXERCISE 137

Problem. Do commercial mouth washes, as ordinarily used, destroy bacteria?

What to use. Three squads of experimenters; four sets of sterilized culture dishes; commercial mouth washes; water.

What to do. Leave one set of culture dishes unexposed for control (*a*). One set of pupils rinse mouth with a teaspoonful of water, and each throw the rinsing into a separate culture dish (*b*); the second set of pupils wash mouth with plain water, then rinse with a teaspoonful of water and save rinsing in culture dishes (*c*); the third set wash mouth with commercial mouth wash, then rinse with a teaspoonful of water and throw rinsing into culture dishes (*d*); label all dishes — names, dates, wash used, etc. — and set aside in same temperature, illumination, etc.

Record. Report average number of colonies, or spots, in each set of dishes. Compare results and record conclusions.

<i>a.</i> CONTROL	<i>b.</i> WATER RINSING	<i>c.</i> RINSING AFTER WATER	<i>d.</i> RINSING AFTER WASH

- Questions.** 1. In what way are commercial mouth washes supposed to produce their results?
2. In what other ways can the desired results be produced?

EXERCISE 138

Vinegar is made by the souring of cider or wine.

Problem. Have microorganisms anything to do with the making of vinegar?

What to use. Hard cider or wine (made by allowing strained apple juice or grape juice to stand uncovered in a moderately warm place for several days); phenol, formalin, or some other antiseptic; litmus paper; bottles.

What to do. Divide the cider into two parts. Leave both bottles open for several hours or overnight. Into one pour a few drops of antiseptic; shake up or stir. Close both bottles loosely with cotton plugs.

After twenty-four hours, test both with litmus paper, and smell. Test thus at intervals until you are sure you have vinegar.

Record. Describe results and explain the difference between the behaviors in the two bottles.

Questions. 1. Why not destroy microorganisms in this experiment by boiling the cider instead of poisoning it?

2. Why not put poison into sweet cider to prevent yeast from fermenting it into hard cider?

3. Why not boil fluids containing alcohol to prevent their turning sour?

EXERCISE 139

The spread of various disease germs has been charged against the common house fly.

Problem. Does the fly actually distribute germs?

What to use. Sterilized culture dishes; living flies caught in various localities; small scissors; clean hands.

What to do. After catching the flies with clean hands, snip off the wings. Place one such fly in each culture dish. Save one or more dishes for control. Apply fingers of the clean hands to the gelatin or agar in other dishes. Label, and leave for twenty-four hours or more.

Record. Note the number and arrangement of colonies in each dish. Describe results, draw your conclusions, and give reasons.

- Questions.**
1. How can you tell that any of the growths were due to *disease* germs?
 2. What is the idea of handling flies with clean hands?
 3. Why cut off the flies' wings?

EXERCISE 140 — *FIELD EXERCISE*

Make a diagram representing an area of about two acres or a city block in your neighborhood, and indicate on it the location of every spot or object in which flies do or may breed.

- Questions.** 1. What can be done to remove these breeding places?
2. Who is responsible for their removal?
3. Who should take action to get the responsible persons to remove them?
4. At what points in the life history of the fly is it best to attack it for the purpose of extermination? Why?

EXERCISE 141 — *FIELD EXERCISE*

Make a diagram representing an area of about two acres or a city block, and indicate on it every spot or object in which mosquitoes do or may breed.

- Questions.**
1. Which of these breeding places can be removed by the individual owner or tenant?
 2. Which ones require the coöperation of several neighbors?
 3. Which ones depend upon the whole community or officials?
 4. What recommendations would you make for ridding the neighborhood of mosquitoes?
 5. At what points in the life history of the mosquitoes is it best to attack them for purpose of extermination? Why?

EXERCISE 142

Various insects are charged with destroying things and material of value to human beings. Find some object or material that shows the injurious action of insects. Find out what insect caused the mischief. Find out all you can about the life history of the insect. Make drawings of the various stages and of the injured material. Indicate the sources of your information.

- Questions.** 1. During what stage of life does the insect carry on injurious activities?
2. What is the relation of these activities to the insect's life?
3. At what stage in its life history is the insect most easily combated?
4. What methods may be used to fight this insect?

EXERCISE 143

Birds have come to be recognized as of such great value to mankind that it is no longer considered right to kill them either for the fun of getting the better of them or for the satisfaction of displaying their plumage. We can, however, have just as much fun, and get other benefits besides, if we use our ingenuity for "shooting" them with a camera or for "capturing" them by means of suitable nesting boxes or by means of food placed where they will come for it regularly without losing their liberty.

If you have a camera, show that you are smarter than the birds by catching one when he is not looking, and bring back a good photograph as evidence of your prowess.

"Capture" a bird in one of the ways suggested, and make a report on your undertaking and its results.

- Questions. 1. What is the name of your prize?
2. How does the bird use its legs?
 3. What is the principal food of this bird?
 4. Of what material does it build its nest?
 5. How many young are usually reared at one time?
 6. Are the young able to care for themselves as soon as hatched?

EXERCISE 144

Problem. How near alike are the individuals or the corresponding organs of individuals of the same kind?

What to use. A hundred or more persons, flowers, leaves, hands, plants, or other convenient individuals or organs of the same kind; a ruler divided into millimeters or into tenths of an inch, or some other suitable measuring instrument — for example, a dynamometer.

What to do. Count the stamens of a hundred buttercups, the ray flowers of a hundred daisies or asters, or the ribs on a hundred elm or beech leaves; or measure the lengths of a hundred beans, corn grains, eggs, or seedlings, or the chest expansion, grip (right and left hands), or circumference of arms.¹

Record. Make a *table* showing the number of individuals for each count or measurement. Make a graphic *diagram* to show the distribution of the variations in count or measurement (cf. Fig. 234 of textbook). *Describe* what you have found.

- Questions.** 1. How do you account for the differences that you find?
2. What striking examples of individual variation have come to your notice?
3. What is the practical importance of the fact that no two human beings are exactly alike?

¹ It is possible that the school records can furnish a hundred measurements of some kind (for example, chest expansion), which may be made to serve.

EXERCISE 145

When a parent is "pure" (either dominant or recessive) with respect to any character, all the germ cells will carry the determiner for that one character; but in a mixed, or hybrid, parent half the germ cells will carry the dominant determiner and half will carry the recessive determiner.

Problem. What are the chances of combining recessive and dominant determiners from two parents that are both of mixed composition?

What to use. Two bags, each containing 100 white beans to represent recessive (R) and 100 beans that have been dipped in ink to represent dominant (D), well shaken up.

What to do. Draw pairs of beans, one from each bag, sixteen times and record the drawings.

	FATHER	MOTHER	APPEARANCE OF OFFSPRING ¹
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

¹ If *any* dominant determiner is present, the offspring appears dominant; if *no* dominant determiner is present, the offspring appears recessive.

EXERCISE 145 (Continued)

- Record.** What is the proportion of dominant from both parents?
What is the proportion of recessive from both parents?
What is the proportion of dominant from father and recessive from mother?
What is the proportion of dominant from mother and recessive from father?
What proportion of the whole offspring is pure?
What proportion of the pure is dominant?
What proportion of the pure is recessive?
What proportion of the whole offspring is mixed, or hybrid?
What proportion of the hybrid is dominant?
What proportion of the hybrid is recessive?
What proportion of all is dominant?
What proportion of the dominant is pure?

- Questions.** 1. Why are recessives always pure?
2. Which characters are more valuable to a species, the dominant or the recessive?
3. What value would it be to know whether a given human trait is dominant or recessive?
4. How would you find out the chances for the appearance of any combination of characters where there are two alternative pairs?

LABORATORY SUPPLIES

The items listed below will suffice for the demonstrations and for the laboratory work of ten pupils. For larger classes order proportionately of the items starred. In many cases suitable substitutes can be obtained or made by teacher and pupils. For example, satisfactory alcohol lamps may be made of old bottles; tin cans and jelly glasses, pickle bottles, and other containers can be put to work in place of expensive vessels; and so on. At the end of the list are some useful directions for preparing various solutions etc.

GLASSWARE

- 1 aquarium, 12-liter
- * 10 battery jars, 2-qt.
- * 10 beakers, 60-cc.
- * 10 beakers, 120-cc.
- * 10 beakers, 250-cc.
- 1 large bell jar, open top, with cork
- * 2 doz. bottles, 8-oz., wide-mouth, with corks to fit
- * 5 doz. bottles, 4-oz., wide-mouth
- * 2 doz. corks to fit above
- * 2 sets reagent bottles marked:
 - Hydrochloric Acid
 - Nitric Acid
 - Ammonia
 - Fehling's solution
 - Acetic Acid
 - Limewater
 - Tincture Iodine
- * 10 cylinders, 500-cc. or 1000-cc., graduated
- * 10 flasks, 250-cc.
- * 10 funnels, 3-in.
- 1 crucible 30-cc., porcelain
- 2 doz. evaporating dishes, 80-cc., porcelain
- * 2 doz. Petri dishes
- 1 box cover glasses
- 1 gross glass slides
- * 10 magnifiers, pocket, double
- 1 lens, double convex
- * 1 doz. medicine droppers
- * 3 thermometers, -10 to +150 C.
- * 10 thistle tubes
- * 4 lb. glass tubing, assorted sizes
- * $\frac{1}{10}$ lb. capillary tubing
- * 4 doz. tumblers
- * 1 gross test tubes, 6" $\times$ $\frac{5}{8}$ "
- * 3 doz. quart preserving jars
- * 1 doz. pint preserving jars

APPARATUS

- 1 trip balance with weights
- * 1 doz. agate pans, 10-in.
- * 6 sets blocks, wooden cubes
- 1 blowpipe, large
- 1 brush, fine camel's-hair
- * $\frac{1}{2}$ doz. brushes, test-tube
- * 10 Bunsen burners or alcohol lamps
- * 10 mirrors, small
- * 10 mirrors, large
- * 5 pairs dividers

- 1 set cork-borers
- 1 egg-beater
- 1 exhaust pump
- 1 file, triangular
- * 5 microscopes, compound, double nosepiece
- * 1 doz. dissecting needles
- * 5 ring stands with rings and clamps
- 1 section-cutter, hand
- * 10 dissecting scalpels
- * 10 pairs dissecting scissors
- 1 storage battery or 6 dry cells
- * 10 test-tube racks
- 1 tape measure
- * 1 doz. paper scales, 150 cm. divided to mm.
- 1 triangle, pipestem
- 1 water bath or double boiler
- 1 Arnold sterilizer
- * 5 pieces wire gauze
- * 3 ft. rubber tubing, $\frac{1}{8}$ -in.
- * 3 ft. rubber tubing, $\frac{3}{16}$ -in.
- * 3 ft. rubber tubing, $\frac{1}{4}$ -in.
- * 3 ft. rubber tubing, $\frac{5}{16}$ -in.
- * 25 ft. rubber tubing for gas burners
- * 1 doz. rubber stoppers, No. 3, 1 hole
- * 1 doz. rubber stoppers, No. 3, 2 holes
- * 1 doz. rubber stoppers, No. 4, 1 hole
- * 1 doz. rubber stoppers, No. 4, 2 holes
- * $\frac{1}{2}$ doz. rubber stoppers, No. 5, 1 hole
- * $\frac{1}{2}$ doz. rubber stoppers, No. 5, 2 holes
- * 2 doz. rubber stoppers, No. 3

CHEMICALS AND SUPPLIES

- * 2 doz. small blotters
- 2 large blotters, blue or green
- * 1 doz. candles, short sizes
- * 1 lb. absorbent cotton
- * 1 package filter paper, 5-in.
- 1 quire filter paper, gray
- * 1 doz. boxes matches
- 1 package splints
- * 4 oz. rubber bands, $\frac{1}{4}$ in. $\times$ 4 in.
- 1 stick sealing wax
- 1 gal. alcohol, grain
- 4 gal. alcohol, wood or denatured
- 1 lb. acetic acid
- $\frac{1}{2}$ lb. alum, potassium
- 4 oz. ammonium nitrate
- 1 lb. ammonium chlorid, granular
- 2 lb. ammonium hydroxid

LABORATORY SUPPLIES (*Continued*)

8 oz. barium chlorid
 1 lb. carbon bisulfid
 4 oz. calcium phosphate
 12 oz. chloroform
 4 oz. chrome alum
 8 oz. copper sulfate
 2 oz. diastase
 1 oz. eosin
 1 lb. ether, sulfuric
 1 lb. Fehling solution, tablets
 4 lb. formalin
 1 lb. grape sugar
 1 gal. gasoline
 2 lb. hyposulfite of soda
 1 lb. ferric chlorid
 2 lb. hydrochloric acid
 1 oz. iodine
 1 lb. lampblack
 1 oz. litmus cubes or red and blue litmus paper
 2 lb. nitric acid
 1 lb. manganese dioxide
 2 oz. magnesium ribbon
 4 oz. magnesium sulfate
 4 lb. mercury, redistilled
 1 oz. pancreatin
 2 lb. sodium carbonate
 1 lb. sodium nitrite
 2 lb. common salt
 1 lb. sodium peroxid (oxone)
 5 lb. sodium silicate
 1 lb. starch
 2 oz. phosphorus, white
 1 oz. phenolphthalein
 1 lb. potassium chlorate, granular
 1 lb. unslaked lime
 1 lb. granulated sugar
 2 oz. vaseline
 1 lb. paraffin
 10 lb. sawdust
 10 lb. sand
 1 bottle India ink
 1 bottle red ink

LIVING PLANTS

Geranium
 Coleus
 Hydrangea
 Spirogyra
 Elodea or other water plants

SEEDS

$\frac{1}{2}$ lb. castor bean
 $\frac{1}{2}$ lb. kidney bean
 1 doz. ears corn on cob
 $\frac{1}{2}$ lb. cotton seed
 1 doz. horsechestnuts
 $\frac{1}{4}$ lb. Windsor beans
 1 package lettuce
 1 package radish
 $\frac{1}{4}$ lb. pea

Roots, stems, and leaves may usually be collected, together with other seeds of wild plants, fruits, mosses, ferns, and so on.

Fungi
 Lichens
 Seaweeds

ANIMAL MATERIAL

* 1 doz. living earthworms
 * 1 doz. living frogs
 * 1 doz. living fish
 * 1 doz. living grasshoppers
 Crayfish
 Snails
 Beetles
 Moths
 Salamanders
 Sandworms
 Mosquitoes and other insects, in all stages
 Frog and toad eggs
 Sea urchins
 Starfish etc.
 Preserved and mounted specimens as opportunity offers

CULTURE MEDIA

Beef bouillon for growing bacteria may be made with 2 tablespoonfuls of beef extract dissolved in 2 quarts of water. Tube in sterilized test tubes; cork with cotton.

Nutrient agar-agar is the best medium in which to grow bacteria. It may be prepared from the following materials: 1000 cubic centimeters of water, 10 grams of salt, 10 grams of peptone, 10 grams of beef extract, a little baking soda, and 10 grams of agar-agar. If agar-agar cannot be obtained, use 100 grams of the best French gelatin.

Dissolve the beef extract in the 1000 cubic centimeters of water. Cut the agar into pieces and add with the salt and peptone. The mixture must then be heated in a double boiler to cause the agar to dissolve. Next add enough baking soda to cause red litmus paper dipped in the mixture to turn blue; that is, the liquid should be *faintly* alkaline. The mass is then filtered within a steam sterilizer by placing a glass funnel in the mouth of an Erlenmeyer flask and one or two layers of absorbent cotton within the funnel as a filter. If the agar, flask, and funnel are kept hot within the sterilizer, the liquid will readily pass through the cotton. A special hot-water funnel-holder may be purchased to do away with the use of a sterilizer in filtering. After filtering, the mouth of the flask should be closed with a plug of absorbent cotton. Then boil in a double boiler for half an hour. If the agar mixture is not clear, it should be filtered through cotton a second time. If care has been taken, the nutrient solution is now ready for use and may be set aside as a stock solution.

If it is desired to make a nutrient solution for molds, omit the cooking soda and add a few drops of *dilute* hydrochloric acid, because molds grow best in a slightly acid medium, while bacteria thrive in a slightly alkaline medium.

To prepare the nutrient agar-agar for use it may be poured while hot into petri dishes which have been previously sterilized with dry heat for several hours and then kept in a dry place free from dust. It is well to sterilize the plates once or twice after they are coated, using a steam sterilizer. Test tubes partially filled with the nutrient jelly are also useful. Immediately after the hot jelly is poured into the test tubes the latter should be plugged with absorbent cotton and then placed in the steam sterilizer.

Fehling's solution (so called in honor of its discoverer) can be purchased in the form of tablets or may be made, and when kept as two solutions will last indefinitely.

Add to 35 grams of copper sulfate (blue vitriol) 500 cubic centimeters of water. Put aside until it is completely dissolved. Call this Solution A.

To 160 grams of caustic soda and 173 grams of Rochelle salt add 500 cubic centimeters of water. Dilute to 1 liter. Call this Solution B.

For use, mix equal parts of A and B.

Iodin solution is made by simply adding a few crystals of the element iodine to 95 per cent alcohol; or, better, by taking 1 gram by weight of iodine crystals and $\frac{2}{3}$ gram of iodide of potassium and dissolving in water; in either case dilute with water to a light brown color.

Limewater can be made by shaking up a piece of quicklime the size of a walnut in about a pint of water. Filter the limewater into bottles and it is ready for use. Close with a stopper smeared with vaseline.

Phenolphthalein. Dissolve 1 gram in 7 grams of grain alcohol; then dilute with water. If the solution appears milky, add a little more grain alcohol.

Hay infusion for the growth of protozoa, normal salt solution, and other aids are described in the "Manual of Suggestions for Teachers."

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