Manual of General Agriculture

BY
EDWARD P. TERRY, M. S.
Assistant Supervisor of Agriculture in the
Los Angeles City Schools

LOS ANGELES, CALIFORNIA

TIMES-MIRROR PTG. & BDG. HOUSE, LOS ANGELES, CAL.

INTRODUCTION

The experiments in this manual represent actual work done by the author's classes during several years teaching of the subject of general agriculture in High Schools in Northern and Southern California. There is sufficient material to occupy the laboratory time of a High School class at least four periods a week for one year. Not all the exercises are suitable for any one locality, but nearly all can be used any place. The manual is not intended to displace any text.

A satisfactory plan for conducting a course in general agriculture is to have each student own a manual and have the school furnish the references to accompany it. As the recitations do not occur every day, one book for three students will be found sufficient. Usually the local library will supply a portion of the books needed. A list of references will be found in the back of this manual.

A note book containing a record of each exercise performed should be kept by the student. The following form is suggested:

Number and statement of exercise.
Exercise.
Result.
Conclusion.

It is unnecessary for the student to copy materials. At the beginning of nearly all the exercises will be found a list of materials needed, but special attention is called to the following, the materials for which cannot be obtained at once: 46, 56, 57, 58, 59, 62, 63, 64, 67, 68, 69.

The author wishes to express his thanks for council and material contributed by Principal E. L. Mitchel, Professors W. T. Clarke, R. H. Loughridge, A. D. MacGillivray, H. H. Whetzel, C. S. Wilson, E. G. Montgomery, Messrs. A. R. Tyler, Geo. C. Roeding and Miss May Kimble. The cuts under Budding and Grafting were taken from Farmers' Bulletin No. 157. With slight changes, exercises 31, 32, 33, 34, 45, 46, 47 and 50 are by Prof. F. E. Edwards.

CONTENTS

PART I. PHYSICAL PROPERTIES OF SOILS.

PART II. CHEMICAL PROPERTIES OF SOILS. SOIL ANALYSIS.

PART V. ENEMIES OF CROPS.

PART VI. TESTING MILK AND ITS PRODUCTS.

PART I. PHYSICAL PROPERTIES OF SOILS.

1. HOW SOILS ARE FORMED. (FIELD EXERCISE.)

(a) Work of Atmosphere.—1. Note any rocks worn away by the friction of wind or sand through the action of the wind. Note any rocks kept exposed to other atmospheric agencies through the action of the wind; note any wind-blown soil; any wind-blown water.

2. Note any evidences of chemical action; oxidation; action of carbon dioxid; "rotten rock." Make a drawing showing successive stages of disintegration from solid rock to soil.

(b) Work of Water.—1. Note any evidences of its solvent power. Fill a small bottle with clear water from a spring or brook and when you return to the laboratory evaporate a few drops of it on a piece of glass or in a test tube, and see if there is any residue; explain.

2. Disintegrating Power of Water.—Note evidences of the washing out of loose material, and of cutting power of the water; of the abrasion caused by gravel, pebbles and stones.

3. Transporting Power of Water.—Why is one stream clear, and another muddy? Note any sand or soil dropped by water.

4. Note evidences of assorting power of water. Draw a section of the bank of a stream, showing stratification.

5. Note evidences of under-ground streams, of landslides, and describe and explain.

2. TAKING SOIL SAMPLES. (FIELD EXERCISE.)

Materials: Spade, paid, two one quart fruit jars, or two bottles with corks.

Select a spot for sampling and remove any leaves and twigs from the surface. Dig into the cleared space a V-shaped hole, with one side of the V perpendicular. On the perpendicular side measure the depth to the change in color, which indicates the division between surface soil and subsoil. With the spade shave thin slices from the perpendicular side to the depth of the surface

soil, collecting the soil in a pail until you have about a quart. If there is no marked line between soil and subsoil, sample to a depth of one foot.

Without filling up the hole go to at least one other part of the field and in a similar manner obtain another sample, place in the pail with the first sample and mix thoroughly. Save about a quart as a sample of the field, and keep air-tight to prevent loss by evaporation.

Continue digging to the depth of about one foot below the surface soil and collect a sample of subsoil by shaving thin slices as before and placing in the pail. Fill up the hole. Return to the original hole and obtain a sample of subsoil, mix the two subsoils and keep air-tight as was done with the surface soil.

3. MICROSCOPICAL EXAMINATION OF SOIL PARTICLES.

Materials: Compound microscope, sand, loam or silt, clay soil, or clay.

Place a few grains of sand on a glass slide and examine with low power of a microscope.

Make drawings of several of the particles and describe them with reference to color; shape (angular, rounded, or irregular); simple or compound (joined together); coarse, medium or fine.

Mix loam or silt with a little water and examine a drop, using medium power. Draw and describe as above.

Mix clay soil with water and examine a drop of the slightly muddy water using the high power. Notice that the soil particles are really minute rocks and humus. Find dark particles of humus. Find flocculated particles of clay, i.e. a number of particles united to form a compound particle. Draw and describe. Keeping a clay soil in good condition is largely a matter of keeping the particles thus flocculated or united into small crumbs.

4. DETERMINATION OF TOTAL MOISTURE IN THE SOIL.

Materials: Four tin pans, sheet iron drying oven*, samples collected in Exercise 2.

Number, mark with your initials and accurately weigh four pans. Record weights in your note book. Run all your experiments in duplicate for the sake of greater accuracy.

Place in pans 1 and 2, 50 grams of surface soil, and in pans 3 and 4, 50 grams of subsoil. Put them in the drying oven for at least five hours at a temperature of 100 to 110 degrees centigrade. Cool to room temperature and weigh at once. The loss in weight represents the total moisture content of the soil.

Tabulate the results as follows:

TOTAL MOISTURE IN SOILS.

Kind of Soil	Pan No.	Wt. of Pan	Wt. of Soil	Wt. of Dry Soil	Loss of Weight	Per Cent Moisture
	1		50g.			
	2					
Avg.						
Kind of Soil						
	3					
	4					
Avg.						

Questions: 1. What were the weather conditions at the time of taking the samples? 2. Approximately, when was the last heavy rain? 3. Does the soil or subsoil have the most moisture? Why?

*A better oven is of copper set on a strong iron frame. It should be about 10 in. high, 10 in. deep, and 12 in. wide. The oven is provided with a centigrade thermometer and has a vent for the escape of moisture. It costs approximately eight dollars. As it is needed throughout the entire course, it is advisable to obtain one.

5. CAPILLARITY.

Materials: Glass tubes having internal diameters ranging from one-sixteenth to one inch, 4 pans, evaporating dish, alcohol or kerosene. Soil and subsoil collected in Exercise 2. For (d), 4 glass tubes at least 4 ft. long and of any diameter up to one inch, the larger the better, pan, sand, sandy soil, loam, clay, small cloth and string.

(a) Place the ends of the tubes side by side in a pan of water. Describe what takes place in the tubes. 1. Does the water rise on the inside of each tube or does it rise on both the inside and outside? 2. If two tubes are placed side by side and as close together as possible, what effect has this on the rise of water between them?

(b) Into a small wide mouth bottle or evaporating dish, pour alcohol or kerosene until it stands about ¾in. deep. Fill the bottle with dry sand or finely divided air-dry soil and press down firmly. Let stand for about 15 minutes, then apply a lighted match. Result? What does this show? This experiment represents accurately the capillary rise of water in soils to replace that used by the plant or that lost by evaporation.

(c) Number and weigh four pans, and place in each of two 50 grams of soil, and in each of the remaining two 50 grams of subsoil. With a pestle or glass rod break up all lumps, at the same time spreading the soil evenly on the bottom of the pans. Set aside and leave undisturbed until the next laboratory period. Weigh again and continue to weigh at each successive period until the weights become constant. Compute the percentage of capillary moisture on the basis of water free soil as found in Exercise 4. The difference between the total moisture and the amount of capillary moisture represents the hygroscopic moisture of soil. Calculate the per cent hygroscopic moisture in the samples under consideration.

(d) Close one end of each tube using a piece of cloth and tying with a string. Fill the tubes with finely

divided air-dry sand, sandy loam, loam and clay. Do not separate the coarse and fine particles. Compact the soil by letting the tubes drop onto a book, taking care to let the tubes drop the same number of times and the same distance. Support the tubes so that the ends dip about one inch in water in the bottom of a pan. Observe the height to which the water has risen at the end of 1 hr., 2 hr., 4 hr., 6 hr., at the next meeting of the class, and at each meeting thereafter for two weeks or more. Keep a paper by each tube showing 1, the height of the moisture, 2, time and day of each reading. Record results in tabular form in your note-book.

Questions: 1. Which tube shows the most rapid rise? 2. At the end of an hour, which shows the greatest rise? 3. At the end of a week? 4. What effect does size of particles have on rapidity of movement?

6. EFFECT OF DRAINAGE ON SOIL TEMPERATURE.

Materials: Five-gallon oil can with one side removed, wooden box approximately the same dimensions.

Fill each with the same kind of soil and apply the same amount of water until drainage begins in the box. There will be no drainage from the can. If necessary, loosen a board in the bottom of the box. Let the two stand out of doors until the following day. Begin as early in the morning as possible and take the temperatures hourly at depths of 1 and 3 inches until 5 P.M. Record results on a piece of paper left by the vessels.

Let some pupil who lives near wet land record the temperatures of this land together with the temperature of adjacent dry land at convenient intervals some Saturday. Compare his temperatures with those of the experiment. Tabulate the results. Give explanations for differences in temperatures.

Question: If drainage effects the temperature, how may it affect a crop?

7. EFFECT OF COLOR ON SOIL TEMPERATURE.

Materials: Two cigar boxes, soot, slaked lime, two thermometers, seeds.

Place well pulverized moist soil into two cigar boxes, filling them about half full. In one-half of one box, bury twelve seeds ½ inch deep, using bean, corn, wheat, or any other quick germinating seeds which may be on hand. In the other half plant 12 seeds of some other plant. Cover both plantings with chalk dust, slaked lime or white ashes to a depth of ¼ inch.

In the same manner plant the same number and the same kinds of seeds in the other box, but instead of using light colored covering, use soot.

Each time the class meets after the second day observe the number of plants showing above the surface, keeping a record of the dates and kinds sprouted on the side of the box. In the morning of a clear day insert a thermometer into each box to about the depth of the sprouted seeds. After a few minutes, when the thermometers have become adjusted to the new temperatures, take the readings. Continue to take the readings hourly throughout the day. Record the results as follows:

DAYS TO SPROUT

Light Soil		Dark Soil	
Beans	Peas	Beans	Peas

TEMPERATURE

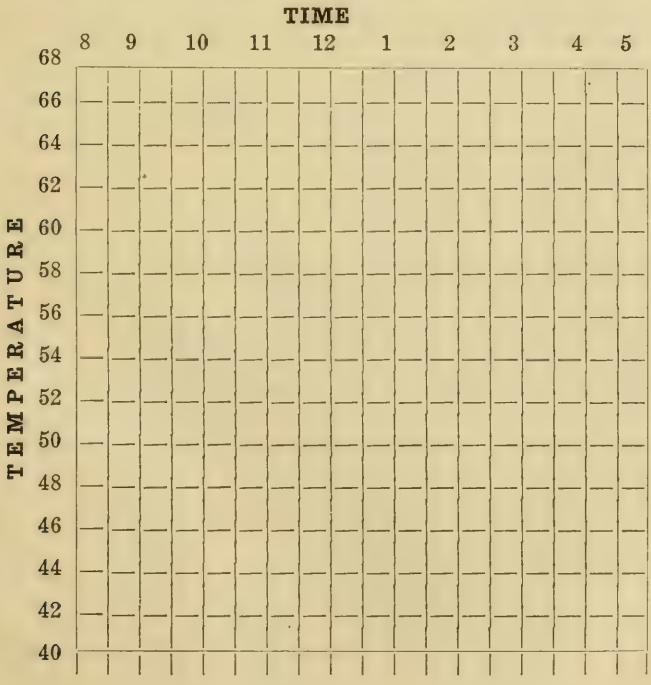
Time	Light Soil	Dark Soil
8 A.M.		
9 A.M.		
10 A.M.		
11 A.M.		
12 M.		
1 P.M.		
2 P.M.		
3 P.M.		
4 P.M.		
5 P.M.		

Question: Which soil shows the higher temperature? Why?

8. EFFECT OF EVAPORATION ON SOIL TEMPERATURE.

Materials: Two tomato cans, 2 thermometers, plotting paper.

Fill two tomato cans with air-dry soil and saturate one with water. Bury the cans side by side in a sunny spot, leaving about ½ inch of the tops above the surface. Insert a thermometer into each to a depth of about 1 inch. The following day as early as possible take the first reading and continue taking readings every hour thereafter until 5 P.M. On plotting paper draw a curve of temperature for each can, using TIME and TEMPERATURE for the co-ordinates as shown in the diagram.



How to plot the curve. Suppose at 8 o'clock it was found that the temperature of the saturated soil was 61 degrees F., a dot should be placed half way between 60 degrees and 62 degrees on the 8 o'clock line; if at 9 o'clock the temperature was 61.5 degrees, the second dot should be placed ¼ of a division higher on the 9 o'clock line. Continue to put dots for all your temperatures. Connect the dots by a straight or broken line.

9. PER CENT OF AIR IN SOILS.

Materials: Three beakers or bottles, graduate, sand, clay, and loam.

Put 25 cc. of sand in one beaker, 25 cc. of clay in the second, and 25 cc. of loam in the third. Fill the graduate to the 50 cc. mark with water and pour on to each sample until the water just rises to the surface. The amount of water required is an approximate measure of the air space, since the water displaces the air. Figure out the per cent of air space in each sample.

Question: What effect does size of particles have on total amount of air space?

10. SEPARATION OF SAND, SILT AND CLAY IN SOILS.

Materials: Tall beaker of about 500 cc. capacity, flask with long narrow neck, mortar, rubber pestle made by inserting a glass rod into a one-hole stopper.

Weigh out exactly 20 grams of air-dry soil and place it in a mortar; add 12 cc. water and rub with the pestle. Let it settle a minute and pour off the muddy water into the tall beaker. Add more water to the mortar and repeat until the water in the mortar no longer gets muddy. The part remaining is coarse sand.

With small amounts of water wash the sand from the mortar through a funnel into a long necked flask.

Add water to the beaker containing muddy water until it is nearly filled. Stir and let stand for an hour, or

until the next meeting. The muddy appearance of the water is due to the clay, which remains in suspension. Siphon off without disturbing the sediment and keep both the siphoned portion and the residue. Fill the beaker again with water, stir, let settle an hour and siphon as before. Repeat until after standing an hour the water above the sediment is clear. Add the siphoned portion to that obtained before. Transfer the sediment to the flask containing the sand. Nearly fill with water and stopper well. Shake and invert on a ring-stand so that the neck is perpendicular. After the small particles have settled, note the different layers of sand at the bottom, to fine silt. Ascertain approximately by volume the percentages of sand, silt and clay.

11. WATER HOLDING CAPACITY OF SOILS.

Materials: Air-dry sand, clay, loam, three student lamp chimneys, cheesecloth, string.

Tie a piece of cheesecloth over the bottom of a chimney, moisten the cloth and weigh accurately. Fill the chimney with dry sand and compact by dropping onto a book a counted number of times from the same height. Weigh it again and stand it in a trough containing several inches of water. Leave it in this position until the surface of the sand becomes thoroughly moist. Remove the tube, wipe dry, and weigh again. Cover the tube with cotton and set it where the water will drain away. Weigh later in the day and at each meeting of the class thereafter for at least 5 days. In the same way prepare tubes using clay and loam or any other soil.

If the soil used is very dry there should be no capillary moisture, but the hygroscopic moisture is still in the samples, hence the results will be too low. For more accurate results the hygroscopic moisture should be determined. Express your results in tabular form.

Questions: 1. Which soil loses water more rapidly? 2. Which takes the longest time to percolate?

12. EFFECT OF HUMUS ON WATER HOLDING CAPACITY OF SOILS.

Materials: Three tin cans, dry well-rotted manure.

Perforate the bottoms of three tin cans. Place a piece of cheesecloth on the bottom of each and weigh, recording the weights on the outside of each. Place in one 95 grams of sand, and 5 grams of well-rotted manure; into another 85 grams of sand and 15 grams well-rotted manure; into the third 75 grams sand and 25 grams well-rotted manure. Saturate each with water and weigh immediately. Write results in each case as follows:

Sand containing 5% organic matter retained —% moisture, etc.

13. EFFECT OF MULCHES AND CULTIVATION ON EVAPORATION FROM THE SOIL.

Materials: As indicated in exercise.

Secure three five-gallon oil cans and cut them in half with a can opener. In case the upper half of any one cannot be made water-tight another must be used. Place an inch of gravel in each. Place in the corner of each a student lamp chimney.

Fill each can with soil to within two inches of the top, slightly compacting the soil. Number the cans from one to six. Cover the soil in number five with one inch of sand. Cover number six with one inch of stable manure.

Weigh each can and record its weight. Bury the cans in an open place until the surfaces inside and out are on the same level. Place them in a row according to numbers and about two feet apart. Pour into each chimney a measured amount of water, allowing time for the soil to absorb it. When the cans without a mulch show dampness on top discontinue. Continue the experiment as follows:

No. 1, check, let alone.
No. 2, cultivate one inch deep once a week.
No. 3, cultivate two inches deep once a week.
No. 4, cultivate three inches deep once a week.
No. 5, let alone. No. 6, let alone.

Continue the experiment at least six weeks, adding measured quantities of water to the cans as they need it to keep the surfaces in good condition for crop growth. At the end of the required time dig up the cans, wipe the outsides clean and weigh. Add to the original weight of each can of soil, the weight of the water added, and subtract from the result the last weight of the can. The difference represents the amount of water evaporated. Tabulate the results.

Questions: How may a farmer obtain an artificial mulch? A natural mulch?

14. EFFECT OF VEGETABLE MATTER ON THE CAPILLARY RISE OF WATER.

Materials: Air-dry soil, sawdust, well rotted manure, tubes as indicated in experiment.

Obtain three glass tubes about an inch in diameter and two feet long. Close the ends of each by means of cheesecloth firmly tied on. Fill one tube with well pulverized air-dry soil and compact slightly. Into a second tube place the same kind of soil to the depth of one-half its length, and then place a two-inch layer of sawdust, and finally fill to the top with soil and compact as above. In the third tube use finely divided well-rotted manure in place of sawdust. Place the tubes so that the lower ends stand about an inch deep in water. At the next laboratory period notice the rise of capillary water. Leave for another laboratory period, at which time write up the experiment and put away the apparatus. Assuming that the crop roots go below the straw or manure plowed under, state the effect of plowing under a large amount of straw or poorly rotted manure.

15. EFFECT OF A MOIST ATMOSPHERE ON DRY SOILS.

Materials: Sand, clay, loam, 3 fruit jars, 3 small receptacles to hold water and small enough to go into the jars, scales.

Place 100 grams of air-dry sand in an accurately weighed fruit jar. Place in the jar a small receptacle con-

taining water. Tightly close the fruit jar and set in the sun. Repeat, using clay and loam. Weigh at each laboratory meeting thereafter until the weight becomes constant. Remove the receptacle at each weighing.

Calculate the amount of moisture absorbed in each case. These amounts are not the **total** moisture since the hygroscopic moisture was always present.

Questions: 1. Which class of soils absorb the largest amount of moisture, and why? 2. If soil absorbs so little moisture from a saturated atmosphere; why do wilted plants "freshen" on a foggy morning?

16. EFFECT OF LIME ON SOILS.

Materials: Clay or clay soil, 2 cigar boxes, slaked lime.

Prepare four moulds one inch in width and the length of the width of the cigar box. Use pieces of one cigar box for the partitions in the other, thus having the four moulds in one box. Weigh out four 100 gr. samples of clay soil and add the following amounts of well-pulverized slaked lime:

No. 1, add none.
No. 2, add one gram.
No. 3, add five grams.
No. 4, add ten grams.

Mix each sample thoroughly in a pan, then add just enough water to make the soil plastic. Mould each sample into a form of a stick by compressing the moist clay in the moulds. Leave in the sun at least a week, or bake in an oven until thoroughly dry. Remove the sticks and determine the weight necessary to break each in the following manner:

Rest the ends of a stick of clay upon supports and suspend from its center a bucket into which sand is slowly poured.

Tabulate the results.

Questions: 1. How does lime effect the tenacity of clay? 2. What effect on the physical condition of clay has lime?

17. ONE EFFECT OF HUMUS, OF SAND, AND OF LIME, ON A CLAY SOIL.

Materials: Four pans, clay, slaked lime, sand.

Fill four pans ¼ full of clay and treat as follows:

To the first add enough water to saturate the clay. Make a note of the amount of water used.

To the second add about ½ its volume of humus or fine, dry, well-rotted manure, and the same amount of water as before.

To the third add ¼ its volume of slaked lime and water, the same as before.

To the fourth add ½ its volume of sand and the same amount of water as before. Make each into a ball and set aside to dry. In a few days examine and see which one can be more easily pulverized with the fingers.

Questions: 1. State the conclusions as to the value of humus, sand, and lime on a clay soil as shown in this experiment. 2. What causes a clay soil to bake. 3. How can the baking of a clay soil be prevented?

18. DETERMINATION OF THE SPECIFIC GRAVITY OF SOILS.

Materials: Graduated cylinder (25 cc. or 50 cc.), sand, clay and loam soils.

In this experiment we are to compare the weights of different soils with the weights of equal volumes of water. Ascertain the weight of 10 cc. of water. Place exactly 10 cc. of water in the cylinder, reading to the top of the column but not including the crescent formed on the surface of the column. This water crescent is called the "meniscus." Pour 10 grams of accurately-weighed sand which has been dried to a constant weight into the water. Shake to expel the air. Take the reading as before, not including the meniscus. Subtract 10 from this reading, and the remainder is the volume of water displaced by the sand. Determine the weight of displaced water and calculate the specific gravity according to the following formula:

$$\text{Sp.} = \frac{\text{Wt. S.}}{\text{Wt. W.}}$$

in which Sp.=specific gravity, Wt. S.=weight of sand or soil, and Wt. W.=weight of water displaced. Calculate the specific gravity of clay and loan soils.*

Questions: 1. What is specific gravity? 2. Why is it necessary to use water-free soils? 3. How does the amount of humus affect the specific gravity?

The specific gravity of the material which forms the great bulk of most soils is about 2.6. But the soil is not a solid mass. It is composed of spherical particles which touch each other at different points. About 50% of a cultivated soil is air-space. Hence this air space reduces the weight of a volume of soil much below the specific gravity of its constituents. In this experiment we really found the specific gravity of the constituents, which is termed "real specific gravity." In the following experiment we are to determine the specific gravity, including air-space, which is termed "apparent specific gravity."

19. DETERMINATION OF APPARENT SPECIFIC GRAVITY OF SOILS.

Materials: Same as in last experiment.

In this experiment we are to determine the ratio of unit weight to unit volume of different soils.

Pour into a dry cylinder 10 cc. water-free sand. Weigh the sand. Having already determined the weight of 10 cc. water calculate the apparent specific gravity according to the following formula:

$$\text{Sp.} = \frac{\text{V. S.}}{\text{V. Wt. W.}}$$

Wt. S.=weight of soil (i.e., weight of 10 cc. soil), V. Wt. W.=weight of water (i. e., weight of 10 cc. water).

Questions: 1. What influence have stones upon the apparent specific gravity? 2. What influence has plow-

*In general when cubic centimeters and grams are used the specific gravity of a body is found by the formula:

$$\text{Sp. Gr. of Body} = \frac{\text{Wt. body.}}{\text{Vol. body.}}$$

ing upon apparent specific gravity? 3. The apparent specific gravity of soils in the field may be taken as an indication of the tilth of soils. Why?

PART II—CHEMICAL PROPERTIES OF SOILS. SOIL ANALYSIS.

If you have taken or are now taking chemistry proceed at once with Exercise 20. If you have not studied chemistry, obtain some chemistry manual and perform the following experiments, as therein described:

(1) Preparation of Oxygen.
(2) Preparation of Hydrogen.
(3) Preparation of Carbon dioxid.
(4) Preparation of Nitrogen.

The teacher should give a demonstration on laboratory manipulation to students unfamiliar with chemistry. See any chemistry manual.

20. ACIDS, ALKALIS, AND SALTS.

Materials: Sulphuric acid, nitric acid, vinegar, red and blue litmus paper, any fruit at hand, sodium and potassium hydroxid, hydrochloric acid, evaporating dish.

(a) Illustration and test for acids: Add a few drops of sulphuric acid to half a tumbler of water. Add drop by drop, tasting each time until the flavor can be distinguished. Do the same with nitric acid.

Compare the taste of each with that of vinegar. Put red and blue litmus paper into the three substances used above. Result? This is a sure test for acids. Test the juice of any fruit at hand. Result?

(b) Illustrations and test for alkalis. Dissolve a small piece of sodium hydroxid (caustic soda) and another small piece of potassium hydroxid (caustic potash), each in about 20 cc. of water. How does each solution feel? Test with both kinds of litmus paper. Result?

Dip your finger into each solution and cautiously taste. This bitter taste, soapy feeling, and alkalin reaction, are the most characteristic properties of alkalis.

(c) Illustration and test for a salt. Pour out 10 cc. of hydrochloric acid into an evaporating dish and add an equal volume (10 cc.) of water. Add sodium hydroxid made in (b) until the solution is neutralized; i. e., until neither shade of litmus is changed in the solution. Evaporate to dryness by heating. Watch the evaporating toward the end and if spattering is too vigorous remove the flame a moment. When evaporation is complete remove the salt and add a little water.

Note the taste and action on litmus. This is a common table salt (sodium chlorid).

Questions: 1. Name three classes of chemical substances and in tabular form give their characteristic properties as indicated in this experiment. 2. What is meant by a neutral substance?

21. PREPARATION OF POTASH.

Materials: Wood ashes, pan, evaporating dish.

Potash is easily prepared from wood ashes. Place wood ashes into a pan, filling it about one-third full. Pour in water until the pan is about two-thirds full and stir vigorously for about two minutes, in order to dissolve the potash in the ashes. When the ashes have settled pour off the clear liquid and test with litmus paper. Result? Potash is one of the alkalis, which always have this effect upon litmus. Notice the soapy feel and the bitter taste.

22. PREPARATION OF CRUDE PHOSPHORIC ACID.

Materials: Bones, mortar and pestle, red and blue litmus paper, sulphuric acid, stirring rod, beaker, filter and filter paper, nitric acid, test tube, ammonium molybdate.*

Obtain some bones of any kind and burn them until white. This white substance is for the most part a combination of phosphoric acid and lime. To remove the lime, take about 10 gr. of burned bone and pulverize in a mortar, transfer to a beaker, add 50 cc. of water and 5 cc. of sulphuric acid and stir with a stirring rod a few min-

*For the preparation of ammonium molybdate see page 28.

utes. The lime will combine with the sulphuric acid and leave the phosphoric acid in solution. By merely testing the solution with litmus paper does not prove the presence of phosphoric acid, even if the blue does turn red, since we have added sulphuric acid and some of this may not have been removed by combining with the lime. Hence we must use a special test for phosphoric acid. Filter and to ¼ of a test tube of the filtered liquid (filtrate) add 3 or 4 c.c. of nitric acid and heat until it just begins to boil. Add ¼ test tube of ammonium molybdate. A yellowish color proves the presence of phosphoric acid.

As a control repeat the experiment, using 10 grams of sand instead of 10 grams of bone. Upon the addition of ammonium molybdate does the yellowish color appear?

23. ALKALI SOILS.

Materials: Three tomato cans, small pan, 3 evaporating dishes, sodium carbonate, sodium chlorid, sodium sulphate, hydrochloric acid.

Among the injurious constituents of many soils of arid regions are certain salts collectively known as "alkali." Whenever the rainfall is scant they are not leached out of the soil as fast as formed and so accumulate. As the rain water evaporates they are left on the surface, where they form a white deposit known as "white alkali." However, there is also a black alkali formed by another salt, sodium carbonate. This is the worst form of all since it combines with the humus or organic matter of the soil to form a black mass, and also corrodes the plant just at the surface of the soil and kills it. Glauber's salt or sodium sulphate, together with common salt or sodium chlorid, and some others, form white alkali which is much less injurious than "black alkali."

Obtain enough soil to fill the cans and divide it into three parts. Put one part into a can untreated. Put another part into the pan. Add 15 grams of powdered sodium carbonate and mix thoroughly, then transfer to another can. To the last part add 5 grams each of sodium chlorid and

sodium sulphate, mix thoroughly and place in the third can. Saturate each, including the first and compact the surface of the soil. Place the cans in a warm place for a week. The first can serves as a check. At the end of the week what is the difference in the appearance of the surface of the soil in the three cans? Sodium carbonate though white, acted chemically with the humus in the soil and formed the black substance which, as the water evaporated, was left on the surface, hence the name "black alkali." The chemicals in the third can did not act chemically, hence came to the surface forming the "white alkali."

Again thoroughly wet the soils, adding only a little water at a time so that the alkali may be washed down into the soil as it dissolves. Beginning as soon as the soils are in condition to work, cultivate the cans to the depth of an inch every day for a week. Why does the alkali not come to the surface again?

Perforate the bottoms of the cans with a nail. Place each in a separate pan and add water a little at a time until about a pint of drain water is collected from each can. Again pack the soil surface and place the cans in a warm place for two or three days. Filter about 100 c.c. portions of each of the drainage waters into separate evaporating dishes and evaporate to dryness. Is there as much residue in the first sample as there is in the second and third? With a stirring rod taste the first residue. Add a few drops of dilute hydrochloric acid to the second residue. An effervescence (frothing) shows carbonates present. Try the first residue in the same way. Is the result the same? Taste the third residue. Is it salty? Does it taste like the first? Have the alkalis been washed from the soil? After the cans have stood for two or three days examine their surfaces. Do they show alkali as before? Draw conclusions from this exercise as to the nature of alkali and methods of ridding the land of it.

24. GYPSUM TREATMENT FOR BLACK ALKALI.

Materials: A tomato can, gypsum, sodium carbonate.

Prepare a can of the same kind of soil as in the last experiment. Weigh out 15 grams each of sodium carbonate and gypsum (land plaster), powder each thoroughly and mix them with the soil before placing it in the can, add water to the soil slowly until it is saturated. Compact as in the last experiment. Place in a warm place for two days and note the incrustation. Is it "black alkali," or has the gypsum changed it? How does the residue compare with that in the third can in the last experiment? If the materials have been well mixed the sodium carbonate will have acted with the calcium sulphate (gypsum) and formed insoluble calcium carbonate (limestone) and sodium sulphate one of the compounds in "white alkali." In this manner the very harmful "black alkali" can be changed to much less dangerous white variety.

Besides containing harmful minerals, most alkali soils are rich in soluble plant food such as nitrates and potassium compounds.

25. ACID SOILS AND HOW TO CORRECT THEM.

An acid soil, litmus paper, evaporating dish, wood ashes or slaked lime, pan.

Not only do we have alkali soil, but to a limited extent in the West we have soils that are acid. They are usually spoken of as sour soils. Some plants, notably clover and alfalfa, will not thrive in such soils because the soil bacteria are hindered by the acid present.

Obtain some such soil or soils from tule land, poorly drained clay soil, and soil from the school yard and test as follows: Boil a sample a few minutes in a small quantity of distilled water and allow the soil to settle.

Place in the dish both kinds of litmus paper. Leave the paper for several minutes as the soil may be nearly neutral, i. e., neither acid or alkalin. Examine the litmus and compare each with the original paper.

Stir into a soil known to be alkalin a small handful of slaked lime or wood ashes and test with litmus paper

to determine when enough has been used to make it neutral. Use distilled water. What might be applied to an acid soil? As in the case of alkali, draining is an effectual remedy.

SOIL ANALYSIS.

There are in the earth's crust about eighty simple substances called elements. Of these only ten are necessary for plant growth.

They are nitrogen, phosphorus, potassium, calcium, iron, surphur, magnesium, carbon, oxygen and hydrogen. In addition to these, sodium, silicon, chlorin and aluminum are found in many plants, but are not essential to plant growth. None of the above elements are found in the plant or in the soil in the elemental form, but are always in combination with other elements to form compounds.

Carbon is derived from the carbon dioxid of the air; hydrogen and oxygen from the water taken up by plants, and the others from the soil. Of the soil elements potassium, phosphorus and nitrogen, and sometimes calcium, are used by plants to a much greater extent than the others. In fact, if the soil is well supplied with these four, so far as plant food is concerned, it may be considered a rich soil. For this reason in a short analysis of soils the amounts of other elements are never considered.

The manner in which these four most important elements exist in the soil is: nitrogen as humus (vegetable mould), phosphorus in phosphoric acid, potassium in potash as in leached wood ashes which by the removal of impurities furnish potassium carbonate, and calcium as lime.

The soil-humus is the chief depository of soil nitrogen and the main source from which plants receive their supply. True, the air about us is composed of four-fifths nitrogen, but abundant evidence shows that plants cannot draw from this bountiful supply. For the most part, humus is derived from decayed vegetable matter, and as there is not a rank vegetation in the arid regions, it follows that the humus content is one of prime importance

in many parts of California and the West. The most vital factor in California agriculture today is the maintenance of humus. This may be accomplished by crop rotation including in the rotation a legume (pea, bean, clover, alfalfa, etc.,) which has the ability to obtain its supply of nitrogen from the air through the bacteria which this order of plants harbors in its roots. Humus may be directly added to the soil in the form of manures and in green crops plowed under. It is customary to estimate approximately the nitrogen content of soils by the proportion of humus present.

26. DIRECTIONS FOR OBTAINING SOIL SAMPLES.

Materials: Spade or post-hole augur, sack or board or oilcloth, quart jar.

From a representative part of the field from which soil is to be analyzed, remove the leaves and twigs from the surface and dig with the spade or bore with the post-hole augur, down to the depth of four feet. Put all spade or augurs-ful of soil on a clean sack or board. Mix all the soil thus taken out, thoroughly on the sack or board, and keep about a quart of this mixed soil, which will represent an average of four feet in the field.

To obtain a more representative sample, several samples may be taken in the same way from different places and then a quart from all of them saved.

PREPARATION OF REAGENTS FOR SOIL ANALYSIS.

(The following should be prepared by the teacher or some trusted pupil and are enough for an entire class.)

Ten per cent solution of caustic potash. Dissolve 20 grams of solid caustic potash (potassium hydroxid) in 200 c.c. of water.

Dilute hydrochloric acid. Dilute two quarts of the commercial acid by pouring the acid into eight quarts of water.

One-half per cent solution of phosphoric acid. Dis-

solve one gram of solid phosphoric acid in 200 c.c. of water.

Molybdate of ammonia. Add ten grams of ammonium molybdate to 25 c.c. distilled water; then add 15 c.c. of strong chemically pure ammonium hydroxid and 150 grams chemically pure nitric acid. Keep warm and if a yellow precipitate appears, pour off the clear liquid for use; if not the liquid is ready for use.

A saturated solution of oxalate of ammonia. Fill a bottle ¼ full of ammonia oxalate, then fill with water and allow to stand until saturated or for several hours.

1.7% solution of nitrate of silver. Add 1.7 grams of silver nitrate to 100 c.c. of distilled water.

Ten per cent solution of barium chlorid. Add 10 grams of barium chlorid to 100 c.c. of water.

Ten per cent solution of ammonium chlorid. Add 10 grams of ammonium chlorid to 100 c.c. water.

27. DETERMINATION OF NITROGEN.

Materials: 10% caustic potash solution, rubber pestle made by placing a one-hole stopper on the end of a stirring rod, mortar, test tube.

Pulverize the soil with the rubber pestle. Place 7 grams in a test tube and add 20 c.c. of caustic potash solution. Boil from ten to fifteen seconds, then allow the heavier portion to settle. The humus is dissolved and the density of the color of the solution is an indication of adequacy or inadequacy. A dense black, non-translucent solution shows the presence of at least one per cent of humus in the soil. A deep brown translucent color indicates the presence of about one-half of one per cent of humus. A light brown color clearly indicates a deficiency of humus.

The test tells us about the humus only, but in all except very arid regions the humus content is an accurate index of the nitrogen content, hence the test is of practical value.

28. DETERMINATION OF PHOSPHORIC ACID.

Materials: Pint of pure sand, dilute hydrochloric acid, stirring rod, phosphoric acid tube.* ½% solution of phosphoric acid, ammonium molybdate solution, funnel, test tube, filter paper, pan, iron pan or iron disc, blue litmus paper, beaker, file, millimeter rule.

(a) First prepare a standard of comparison** by taking a pint of pure sand and pouring on it about three times its volume or three pints of dilute hydrochloric acid. Allow to stand for an hour or more, stirring from time to time with a strong stirring rod. Place in the sink and allow water to run through it for several hours, until water after being thoroughly stirred up with it, no longer gives any acid reaction with litmus. Dry the sand and take 25 grams for this experiment, saving the rest for subsequent tests. A good content of soluble*** phosphoric acid in the soil is one-tenth of one per cent. We will add this amount to the sand and make a test. To the 25 grams of sand add 5 c.c. of a ½% solution of phosphoric acid. This gives .025 gram in 25 grams of sand or .1 of 1%. Take two grams of the sand which has been moistened with the acid and burn for five minutes on a red-hot iron for the purpose of removing the vegetable matter or humus. Place in a test tube and add 3 or 4 c.c. of pure nitric acid. Heat until it just begins to boil, then add 2 or 3 c.c. of tap water and filter into a test tube. Wash out the acid by allowing 4 or 5 c.c. of water to run through the sand into the filtered liquid and add to the filtrate, its own volume of a solution of molybdate of ammonia. Then place the test tube in a beaker of hot water

*These tubes can be obtained of Justinian Cairne Co., 573 Market St., San Francisco, California, at 40 cents each or $4.20 per dozen.

**A standard of comparison is best made by taking two grams of a soil in which the phosphoric acid has been accurately determined, instead of purifying sand, etc.

***That is, soluble in the acids used in making tests. The soil may contain a great deal more phosphoric acid in insoluble form, but this will not appear in the test and is not directly available to the plant.

until the precipitate has come down. Pour off the clear liquid at the top and transfer the rest to the phosphoric acid tube. Suppose that the precipitate, which is molybdo-phosphate of ammonium, when it has settled into the neck of the tube forms a column one centimeter high. This would indicate a content of .1 of 1% of phosphoric acid in the soil. With a file mark the height of this column after making sure that the test is correct either by comparison with tests of others or by repeated tests.

(b) Test soil as follows: Take two grams of soil, burn it on a red-hot iron for five minutes or until it is light gray in color. Place in a test tube and add 3 or 4 c.c. nitric acid, then heat until it just begins to boil; add 2 or 3 c.c. of water and filter into a test tube. Allow 4 or 5 c.c. of water to run through the soil into the filtrate and add to the filtrate its own volume of ammonia molybdate, then place the test tube in a beaker of hot water until the precipitate has come down. Pour off the clear liquid at the top and transfer the rest to the phosphoric acid tube. If the precipitate is above the standard phosphoric acid mark we know that the soil is well supplied with phosphoric acid, i. e., there is more than .1 of 1%. Use a millimeter rule and calculate the exact per cent.

29. DETERMINATION OF LIME.

Materials: Whiting, sand treated with dilute hydrochloric acid, test tube, saturated solution of oxalate of ammonia, ammonium chlorid, file, funnel the neck of which is not more than one-eighth inch in diameter and closed at the bottom by heating in a hot flame, filter paper, beaker, millimeter rule.

(a) First prepare a standard of comparison as follows: To exactly 25 grams of sand previously treated with hydrochloric acid, add a quarter of a gram of whiting, which will give a content of one per cent of carbonate of lime in the soil. Thoroughly mix with the sand. Place a gram of this sand in a test tube and add 1 c.c. chemically pure hydrochloric acid. Heat until it just begins to boil, then add ammonia water until a permanent precipi-

tate appears. Filter while hot, then add a drop of ammonium chlorid and 1 c.c. saturated solution of oxalate of ammonia. Transfer to the closed funnel and allow the precipitate of oxalate of lime to settle. Suppose the precipitate forms a column 2 c.m. high. This would indicate a content of 1% of carbonate of lime. With a file mark the height of this column after verifying your result, either by comparing with tests of others, or by repeated tests. The height of this mark becomes the standard of comparison for future tests.

(b) Test samples of soil in a similar way as follows:

Place one gram of soil in a test tube. Add 1 c.c. hydrochloric acid and heat until it just begins to boil. Add strong ammonia until a permanent precipitate appears; filter while hot, add a drop of ammonium chlorid and 1 c.c. of a saturated solution of oxalate of ammonia.

Transfer to the closed funnel and allow the precipitate to settle. Calculate the per cent of lime by using a millimeter rule. Our standard indicates a lime content of one per cent. In a clay soil 1 to 2% is about right. In a sandy soil three-tenths to five-tenths of one per cent is good. Ten to fifteen per cent is an excess in any soil.

30. DETERMINATION OF ALKALI.

Materials: Sand, sodium carbonate, sodium chlorid, sodium sulphate, filter and litmus paper, nitric acid, silver nitrate solution, barium chlorid, and phosphoric acid tube.

(a) Prepare a standard of comparison as follows: To 20 grams of sand which has been treated with hydrochloric acid, add 4 c.c. of a solution made by dissolving in 100 c.c. of distilled water 1 gram of sodium carbonate, 1 gram sodium chlorid and 3.3 grams sodium sulphate. This gives a content in the soil of one-tenth of one per cent sodium carbonate, two-tenths of one per cent sodium chlorid (common salt), and three-tenths of one per cent sodium sulphate. These are all excessive and harmful amounts and a soil which contains as much of any is unsuitable for ordinary crops.

(b) Test the standard sample and then 20 grams each of several samples of alkali soils as follows: Place filter paper in a funnel and put the sand or soil on it; add 20 c.c. of water and let it leach through into a beaker, then divide the leachings into two equal parts. Divide one part into fourths, dilute three of them with one, two and three volumes of water respectively.

1. **Sodium Carbonate.** Test the undiluted part, then each diluted part with red litmus paper. The rapidity with which the paper turns blue indicates the amount of black alkali or sodium carbonate. If it quickly turns deep blue it indicates an excessive amount; one-tenth of one per cent or more. If it turns blue very slowly it indicates a lesser amount. Save the original samples as a standard of comparison for samples of soil and label each.

2. **Sodium Chlorid.** Take half of the unused leachings and test for common salt as follows: Add a few drops of nitric acid and then a drop or two of a 1.7 per cent solution of silver nitrate, a white curdy precipitate of silver chlorid, shows an excessive amount of salt (two-tenths of one per cent or more) and from this we may find, in testing soils, all amounts down to a trace which gives only a slight milkiness on the addition of silver nitrate.

3. **Sodium Sulphate.** Take the remainder of the leachings and test for sodium sulphate as follows: Add a few drops of hydrochloric acid, heat, then add a few drops of barium chlorid to the hot solution. Transfer to the phosphoric acid tube and in the case of the prepared sand mark the height of the column of precipitate which is barium sulphate. This indicates a content of three-tenths of one per cent, which is an excessive and injurious amount. With this as a standard we may calculate the amount of sodium sulphate in soil samples. (Record the sodium sulphate mark as before, to be used as a standard.)

PART III—CHEMISTRY OF PLANTS.

31. MOISTURE IN THE PLANT.

Materials: A small pan with a capacity of 100 to 150 c.c., a balance sensitive to 10 milligrams, drying oven, thermometer.

Dry the pan and weigh it carefully. Nearly fill it with finely cut stems and leaves of a fresh plant that is growing vigorously. Weigh again. Record all weights. Get the weight of the plant material by the difference. Place the pan in the oven and keep the temperature at 100 to 105 degrees C. for five or six hours. Cool and weigh. Heat in the oven again for an hour and cool and weigh. If the weight is constant, the material is dry. If there is an appreciable difference shown by the two weighings, repeat the heating, cooling, and weighing till a constant weight is shown. The total loss in weight represents the amount of water held mechanically in the plant. Calculate the amount in per cent of the original weight of the plant material. Our ordinary growing plants hold 75 to 95% of water in this way. Save the dry material for Exercises 32 and 34.

32. COMPOSITION OF DRY MATTER OF PLANTS.

Materials: Porcelain crucible, 250 c.c. flask, wire triangle, iron tripod or ring stand.

Nearly fill the crucible with dried plant material and heat it over the burner till the substance begins to blaze. Remove the burner and quickly hold over the blazing material a flask, nearly full of cold water and clean and dry on the outside. Note the condensation of water on the cold surface of the flask. As the material used was dry, this water must have been produced by the breaking up of the plant tissues. It consists of **oxygen** and **hydrogen,** two elements of plant composition. This, as well as the mechanically held water, was derived from the soil water, having risen through the roots. Remove the flask and observe the charred mass remaining in the crucible. It is principally **carbon** derived from the air. Continue to heat

the crucible until there remains a light, gray colored ash. These ashes show the part of the plan that is derived from the soil. How does it compare with the part derived from the water and air (the part that has burned away)? Save the plant ash for Exercise 33.

The average plant derives about 9.0% of its weight from the air, 89.5% from the water and 1.5% from the soil. The air always supplies its portion to the plant without assistance of the farmer; our California soils are generally quite fertile and with proper cultivation will usually yield their portion of the food; but to supply the large amount of water that the plant soil requires, offers a problem that is becoming very serious, and one to which we are prone not to give proper consideration.

33. COMPOSITION OF PLANT ASH.

Materials: Evaporating dish, funnel, filters, test tubes, three inches of platinum wire (fine iron wire may be used), cobalt blue glass (or a blue glass bottle), glass stirring rod, concentrated hydrochloric acid, concentrated nitric acid, distilled water, solutions of potassium sulphocyanate, sodium phosphate, silver nitrate, barium chlorid, ammonium molybdate, and ammonia.

Place in an evaporating dish about ½ gram of the plant ash left from the previous exercise. Add to it 5 c.c. each of distilled water and concentrated hydrochloric acid and a few drops of concentrated nitric acid. A rapid frothing, or effervescence, when the acid is added, proves that **carbon** is a constituent of the ash. Heat the mixture to boiling and evaporate it nearly to dryness. Add 10 c.c. distilled water and stir well with a glass rod. The small amount of white insoluble matter contains the **silicon** of the ash. Filter and wash the residue on the filter with a little distilled water and add the washings to the filtrate. To this add ammonia with constant stirring till the solution smells strongly of ammonia, and heat to boiling. Filter and wash the residue as above and save the filtrate and wash-

ings to test for calcium. To the residue on the filter add a few drops of hydrochloric acid, and to the liquid that passes through add a drop of potassium sulpho-cyanate solution. A red color proves **iron.** Heat to boiling the filtrate saved to test for calcium and add 5 c.c. ammonium oxalate solution. A milky white precipitate shows **calcium** in the ash. Filter and wash as above and divide the filtrate and washings into two parts. To one part add slowly drop by drop 5 c.c. sodium phosphate solution. Add 5 c.c. strong ammonia. A white precipitate forming on standing (immediately if there is much magnesium) proves **magnesium** a constituent of the plant ash. Place the remaining half of the above solution in an evaporating dish. Evaporate to dryness and heat to a dull redness if possible, or till white vapors no longer come off. Cool and add to the residue a drop or two of hydrochloric acid. Heat a platinum wire in a colorless gas flame till it gives no yellow color to the flame. Dip the wire into the residue and again heat it in the colorless flame. A bright yellow color imparted to the flame proves **sodium.** Repeat the above platinum wire test, observing it through a dark blue glass or a blue bottle that will shut out the yellow color. A violet color, visible only through the blue glass, proves **potassium** to be in the ash.

To a fresh portion of about half a gram of plant ash add 5 c.c. each of distilled water and strong nitric acid. Heat to boiling, add 10 c.c. more of distilled water and filter. Divide the filtrate into three parts. To one part add 2 c.c. silver nitrate solution. A white precipitate, or a milkiness imparted to the solution, proves **chlorin** in the ash. To the second add 5 c.c. ammonium molybdate solution and heat to blood temperature. Let stand for a while and a yellow precipitate will prove **phosphorus** in the ash. To the last portion add 2 c.c. barium chlorid solution. A white precipitate or a milkiness proves **sulphur.**

34. NITROGEN IN PLANTS.

Materials: Hard glass test tube, one-hole stopper to fit test tube, glass and rubber tubing for delivery tube, litmus paper, test tube, soda-lime.*

Mix a gram of the dried plant material from Exercise 31 with ten grams soda-lime. Place the mixture in a hard glass test tube about an inch in diameter. Close the tube with the one hole stopper connected with a delivery tube that dips into a test tube of distilled water in which is placed a few small pieces of red litmus paper. Apply strong heat to the hard glass test tube for four or five minutes or more. Ammonia is formed from the plant nitrogen and this passing over dissolves in the water. If the litmus paper turns blue it is a proof that the plant contained **nitrogen.**

35. PLANT NUTRITION.

Materials: Ten glass tumblers, wrapping paper, paraffin, large pan, easily bent wire, six vessels that will hold over 500 c.c. each, 100 Canadian field peas germinated in moist sawdust, six quarts of distilled water, 2 grams of calcium nitrate, 1 gram potassium nitrate, .5 gram magnesium sulphate, .5 gram potassium acid phosphate, 1 gram sodium acid phosphate, .5 gram sodium nitrate, .5 gram sodium chlorid, .1 gram sodium sulphate, .1 gram magnesium chlorid.

For demonstrating the necessary elements for plant growth, water cultures are employed. A water culture containing the elements, nitrogen, phosphorous, potassium, calcium, magnesium, sulphur and iron, in the form of soluble compounds (salts) dissolved in distilled water will afford more or less perfect growth. This kind of water culture is known as a full nutrient solution. These seven elements, in addition to hydrogen and oxygen found in water, and carbon, supplied by the carbon dioxid of the air, are those necessary for green plants generally.

*Soda-lime is a mixture of caustic soda and quick lime, obtainable in tight bottles; it forms an eager absorbent of carbon dioxid.

The absence of any one will be readily shown in the growth of the plant. As the seed contains a considerable amount of plant food, no marked difference in growth may be noted the first few days, even though one or more of the necessary elements be absent. Where the necessity of an element is to be determined it is omitted from the water culture and replaced by some unnecessary compound.

For the cultures obtain 10 glass tumblers and make a cover of paraffined paper for each by dipping ordinary wrapping paper into a pan of melted paraffin. The paper may be held in place by a string tied around the side of the tumbler. Do not tie on the covers until directed.

Thoroughly clean six vessels and make up the following stock nutrient solutions:

For calcium and nitrogen use calcium nitrate, 2 grams in 500 c.c. distilled water.

For potassium and nitrogen use potassium nitrate, ½ gram in 500 c.c. distilled water.

For magnesium and sulphur use magnesium sulphate, ½ gram in 500 c.c. distilled water.

For potassium and phosphorous use potassium hydrogen phosphate, ½ gram in 500 c.c. distilled water.

For potassium (in different form than above) use potassium chlorid, ¼ gram in 500 c.c. distilled water.

For iron use ferric chlorid, two drops in 500 c.c. distilled water.

Equal quantities of the above solutions taken will give a full nutrient solution in proper proportions.

Set up the following series of cultures:

I. One culture in distilled water.

II. One culture in tap water.

III. One culture in full nutrient solution. (Use 40 c.c. each of the six solutions prepared.)

IV. One culture in full nutrient solution minus nitrogen (1) For calcium nitrate substitute 40 cc. calcium chlorid made by dissolving .4 gram in 100 cc. distilled water.

(2) For calcium nitrate substitute 40 cc. potassium chlorid made by dissolving .1 gram in 100 cc. (Save the remainder for V.)

V. One culture in full nutrient solution minus phosphorous. For potassium hydrogen phosphate substitute 40 cc. potassium chlorid made in IV (2.)

VI. One culture in full nutrient solution minus potassium.
(1) For potassium hydrogen phosphate substitute 40 cc. sodium hydrogen phosphate made by dissolving .1 gram in 100 cc. distilled water.
(2.) For potassium nitrate substitute 40 cc. sodium nitrate made by dissolving .1 gram in 100 cc. of distilled water.
(3) For potassium chlorid substitute 40 cc. sodium chlorid made by dissolving .4 gram in 100 cc. distilled water.

VII. One culture in full nutrient solution minus calcium. For calcium nitrate substitute 40 cc. sodium nitrate in the proportion .4 gram in 100 cc. distilled water.

VIII. One culture in full nutrient solution minus magnesium.
For magnesium sulphate substitute 40 cc. sodium sulphate made by dissolving .1 gram in 100 cc. distilled water.

IX. One culture in full nutrient solution minus sulphur. For magnesium sulphate substitute 40 cc. magnesium chlorid made by dissolving .1 gram in 100 cc. distilled water.

X. One culture in full nutrient solution minus iron.
For ferric chlorid substitute 40 cc. sodium chlorid made by dissolving a trace in 500 cc. distilled water.

Place the covers over each of the ten tumblers and tie them securely in place. Punch ten holes in each cover

large enough for the roots of the previously germinated Canada field peas to go through. Select 100 of the most vigorous plants and arrange ten in each tumbler so that the roots are below and tops above the covers. In about two weeks it will be necessary to make a wire frame to support the plants. Place the tumblers in a sunny place and allow the culture to grow four weeks. During this period every few days add distilled water so that the quantity of the solution remains about the same.

Make notes weekly concerning the general vigor of the cultures. Final notes should include (1) Average length of tops and of roots of each culture, (2) Green weights of tops and of roots.

36. NITROGEN NODULES.

Go out and dig up (without injury to the roots) a specimen of as many of the following as are conveniently near: a bean, a pea, a clover, an alfalfa, a lupine. These plants all belong to the same family, "leguminosæ," and are commonly called "legumes." Examine the roots for very small knots called "nodules." Also dig up the roots of some cereals and examine them for nodules. Do you find any? Draw one root system showing nodules.

The nodules are the home of bacteria. (See Exercise 65, first paragraph.) These minute organisms are able to use the free nitrogen of the soil air and combine it with the mineral matter of the soil to form nitrates. The plant cannot use free nitrogen but flourishes on the nitrates which the bacteria offer in return for the home provided by the legume. The plant satisfies its needs from the nitrates thus produced and any excess remains in the soil for future crops. This suggests a reason for crop rotation practice of following a legume crop (a nitrogen food producer) by a cereal crop (a nitrogen food consumer.)

37. TEST FOR THE PRINCIPAL CLASSES OF PLANT COMPOUNDS.

Materials: Knife, test tube, iodine solution*, Fehling's solution†, 10% solution copper sulfate, 10% solution potassium hydroxid, evaporating dish.

(a) Carbohydrates. Starch. Cut a small potato in half. Peel and cut into small slices or rub on an ordinary grater a small portion and collect the pieces or gratings in a small dish of cool water. Boil and allow the solution to cool. Add a drop of iodine. A deep blue color proves the presence of starch. To another piece of potato add a drop of iodine. Result?

Sugar. Cut another piece of potato into very thin slices and place in a test tube. Test for grape sugar with Fehling's solution as follows: Measure out 2 c.c. of solution 1, and add to it 5 c.c. of solution 2, and 3 c.c. of water. Add this to the test-tube containing the potato and boil two or three minutes. A red precipitate (sediment) indicates the presence of grape sugar. If the red precipitate does not appear soon, allow the boiled solution to stand until next laboratory period.

There is no elementary test for cane sugar.

(b) Proteids. Cut cross section of beans and potato and carefully touch the cuts with a glass rod that has been dipped in nitric acid. A yellow color should appear which will become more intensely yellow if ammonia is applied. Try it. This coloration is due to the action of the chemicals on the proteids in the substances tested.

Optional test. Pour a small quantity of the white of an egg, which is a good example of protein, in an evaporating dish, and barely cover with a 10% solution

*Iodin solution is prepared by dissolving potassium iodide in water (about one part to seventy-five of water) and adding iodine crystals until the solution becomes dark brown in color.

†Fehling's solution is made by dissolving 34.65 grams of copper sulfate in 200 c.c. of water to make solution 1. To make 2, dissolve 173 grams of sodium potassium tartrate (Rochelle Salt) in 480 c.c. of a ten per cent solution of sodium hydroxid. Use as directed in the experiment, making up the reagent fresh whenever needed.

of caustic potash (potassium hydroxid.) Warm but do not cook the egg. Add a few drops of a 10% solution of blue stone (copper sulfate) and let stand until next laboratory period. At first a greenish blue color appears and in ten or fifteen minutes a beautiful violet color proves the presence of proteids.

(c) Fats and Oils. Grind a tablespoonful of oats, barley, or corn. If the grinding cannot be conveniently done use bran, flaxseed, or any ground feed. Place in a bottle and pour over it 15 c.c. of ether‡. Stopper, shake well at intervals for half an hour or let stand until the next laboratory period. Filter the liquid into a clean evaporating dish and allow the ether to evaporate in the open air. The residue is plant fat and oil.

38. OCCURRENCE AND EXTRACTION OF STARCH.

Materials: Compound microscope, piece of potato, grater, beaker, evaporating dish, test tube holder, glass tube 8 in. long, lime water, ring-stand, one-hole rubber stopper for test tube, cheesecloth.

(a) Examine a thin section of potato under the microscope. Make a careful drawing of the structure of the cells and granules within. Cover the section with a cover glass and introduce a minute trace of iodine solution at the edge of the cover glass. Make a shaded or colored (blue pencil) drawing of the object.

(b) Clean and peel one end of a potato. Rub it on a grater and collect the gratings in a beaker of cold water. Strain through a cheesecloth and allow the cloudy liquid to stand until the starch settles. Pour off some of the liquid and evaporate some of it to dryness in an evaporating dish. Describe the residue.

Heat a small portion of starch in a test tube. What does this show starch to contain? Take another test tube and fill it one-third full of lime water. Insert into the test tube containing the starch a one-hole rubber stopper. Bend a glass tube 8 inches long into a right angle, and

‡Do not place ether near a flame.

insert one end into the stopper and the other end into the lime water, arranging the apparatus on a ring-stand. Gently heat the starch in the test tube. The milky appearance of the lime-water indicates the presence of carbon dioxid in starch. Test the breath for carbon dioxid gas by blowing through a tube into a test tube one-third full of clear lime water.

Questions: 1. What two compounds does starch contain? 2. What three elements does starch contain? 3. To what class of plant compounds does starch belong, organic or inorganic?

39. INVERSION OF CANE SUGAR (SUCROSE).

Materials: Cane sugar, evaporating dish, sulphuric acid, sand bath, Fehling's solution, calcium carbonate, filter paper, funnel.

There is no direct simple test for cane sugar but by changing the cane sugar to grape sugar we get an indirect test. This change is known as inversion of cane sugar.

Place 2 grams of sugar in an evaporating dish and add 30 c.c. of water and 2 c.c. of sulphuric acid. Heat fifteen minutes on a sand bath, replacing the water lost by evaporation. Neutralize with calcium carbonate. Determine when neutral by using litmus paper. Add more water for filtration if necessary. Test with Fehling's solution. Result?

Take one-tenth gram of cane sugar, dissolve in 10 c.c. of cold water and test with Fehling's solution. Result?

Question: 1. What is the object of adding calcium carbonate?

40. PREPARATION OF GLUCOSE (GRAPE SUGAR.)

Materials: Evaporating dish, sand bath, starch, calcium carbonate, litmus paper, iodin solution, filter, stirring rod, Fehling's solution.

Add 10 drops of sulphuric acid to about 35 c.c. of water in an evaporating dish. Heat on a sand bath until the boiling point is reached. Add 1 gram of pulverized starch, noting its appearance immediately after adding. Heat 25

minutes, stirring occasionally, and replacing water should too much evaporate. Add calcium carbonate to neutralize the sulphuric acid. Determine when neutral by using litmus paper. When neutral filter and wash the residue with 15 c.c. of water. Test a few drops of the filtrate with iodin. Have the properties of the starch been destroyed? Evaporate the remainder in an evaporating dish to about 10 c.c. Test for glucose or grape sugar with Fehling's solution.

41. ESSENTIAL OIL FROM PLANTS.

Materials: Tea, clover, or alfalfa, glass stoppered retort (as used in preparation of nitric acid), large test tube, wire gauze.

Place 5 grams of tea into the glass stoppered retort and add 50 c.c. water. Place the end of the retort in a test tube one-third full of water. Support the apparatus on a ring stand, allowing the retort to rest on a wire gauze. Apply heat and distill 3 or 4 c.c. Observe the color of the distillate (in the test tube.) Is the essential oil from tea volatile? Repeat the experiment, using clover or alfalfa.

42. EXTRACTION OF PROTEIDS.

Materials: Flour, cheesecloth, pan, 10% solution of sodium chlorid, test tube.

A good illustration of protein is gluten, obtained from wheat flour. Mix in a pan with a glass rod 30 grams of flour and sufficient water to make a stiff dough and let stand half an hour in order that the physical properties of the gluten may develop. Place in a cheesecloth and wash in a stream of water, working the dough gently with the fingers.

Continue washing until the water runs away clear, which indicates that all the starch has been washed out. The gluten remains on the cheesecloth. Treat a small portion of gluten with a 10% solution of sodium chlorid. Does it dissolve?

In California there are no definite divisions between winter and spring wheats. But in localities where this

distinction is marked, or where flour from winter and spring wheats can be obtained, treat a sample of each as indicated, and compare the two.

43. EXTRACTION AND DECOMPOSITION OF CHLOROPHYLL.

Materials: Green leaves, preferably of young growing grass or cereal, large test tube, two small test tubes.

Place some green leaves into a large test tube, filling the tube about one-third full. Pour alcohol over them until the test tube is about one-half full. Boil for about two minutes. Transfer the liquid to two small test tubes, pouring the same amount into each. Note the color of the chlorophyll extract.

Place one solution in direct sunlight and the other in complete darkness. At the end of an hour and again at the next meeting compare the two.

Questions: 1. What is chlorophyll? 2. What is the effect of light on chlorophyll?

44. DETERMINATION OF OIL IN FLAXSEED.

Materials: Ground flaxseed, ether or benzine, evaporating dish, filter, filter paper, ring stand.

(a) Weigh out 25 grams of flaxseed and add 25 c.c. of ether or benzine.* Let stand about fifteen minutes and then filter into an evaporating dish. Wash the meal by pouring over it, a little at a time, about the same amount of ether or benzine. Let the liquid stand in a good draft until the next laboratory period or until it has lost the odor of the liquid used. Weigh the remaining oil (fat) and calculate what per cent of the ground seed was oil. (A small amount of fat will still be left in the residue.)

(1) Describe the oil obtained. (2) Of what use would it have been to the plant?

Optional. Oil from yolk of egg. Repeat the above experiment, using 10 grams of the yolk of a hard-boiled egg and add 10 c.c. of ether or benzine.

*Do not bring ether or benzene near a flame.

(1) Compare the appearance of this oil (fat) with that from flaxseed. Are the oils in flaxseed and the yolk of an egg volatile?

45. ABSORPTION OF MANURE BY THE SOIL.

Materials: A pan, a tall quart can, a large funnel, a beaker and quart of well rotted stable manure.

Soak a quart of well rotted stable manure for two days in enough water to cover it. Perforate the bottom of a tall, narrow can, holding about a quart, and fill it with dry soil. Set it in a large funnel. Pour off the water from the manure and note its color. A large part of the fertilizing value of the manure has dissolved in the water. This suggests that the practice of piling manure in heaps and letting it lay exposed to the leaching action of the winter rains is a very wasteful one. Slowly pour the manure water over the soil and let it drain through into a beaker. Compare the color of the drainage with that before adding it to the soil. Has the soil absorbed the valuable part of the manure? A common practice is to pile a load of manure in a place, throughout the field, and scatter the piles after they have rotted all winter. Will this give an even distribution of the fertilizing part of the manure?

46. FERTILIZER FIELD TESTS.

This set of tests should be carried on in co-operation with some progressive farmer whose farm is near the school. Select a field that is not yielding well. Lay out the field of uniform soil, or as nearly as may be, in plats of 2 rods or 33 feet by 4 rods or 66 feet. There will be one-twentieth of an acre in each plat. Put stakes at the corners and keep an accurate record as to treatment. When the soil is thoroughly prepared, and just before seeding, apply the fertilizers by sowing them broadcast, being careful that all parts of the plat receive the same quantity of fertilizers. The eight plats should be fertilized as follows:

No. 1. No fertilizer, serving as a check.

No. 2. 10 lbs. sulphate of potash. (Approximate cost 4c per lb.)

No. 3. 20 lbs. acid phosphate. (1½c per lb.)

No. 4. 10 lbs. nitrate of soda, (3c per lb.)

No. 5. 10 lbs. nitrate of soda, 20 lbs. acid phosphate.

No. 6. 10 lbs nitrate of soda, 10 lbs. sulphate of potash.

No. 7. 10 lbs. sulphate of potash, 20 lbs. acid phosphate.

No. 8. 10 lbs. nitrate of soda, 10 lbs. sulphate of potash, 20 lbs. acid phosphate.

No. 9. A half ton of stable manure.

No. 10. Special. Some fertilizer not included in the above but used locally as 2 lbs. land plaster (gypsum, or cow manure, or sheep manure, etc.) Plaster and manure show more marked results the second year.

Sow all plats exactly alike with the same kind of seed. One of the crops ordinarily raised in the community, such as corn, wheat, barley, etc., should be used. If the class is large enough three or four set of plats as described above may be used, each being sowed to a different crop. When the crop is ripe, each plat should be separately cut and threshed and the yield of grain and straw both carefully weighed. A study of the yields of the plats as compared with the fertilizers applied will give the necessary data to determine what combination of fertilizing material will cause the field to increase its yield of that particular crop, and will give a partial check on the deficiency of the soil in any particular plant food. A second year of tests on the same plats will serve as a valuable check on the first year's results.

Let the students devise a series of tests to show the fertilizer requirements of the fruit trees in some nearby orchard. Fertilizers should not be applied around the base of the tree or much injury may be done. The feeding roots are spread over an area equal to or greater than that covered by the branches, and the fertilizer should be

spread accordingly. The trees should be numbered and the results noted for two or three years. The fertilizers have little apparent effect on the trees for the first year.

PART IV—AGRICULTURAL BOTANY AND PLANT PROPAGATION.

47. CONDITIONS NECESSARY FOR GERMINATION.

Materials: Six tomato cans, peas, or beans.

Number the cans from 1 to 6. Fill numbers one, four and six with rich, moist, loamy soil. Fill number three with the same kind of soil, having first thoroughly air-dried it. Leave numbers two and five without soil. Plant in each of the soil-filled cans six seeds of peas or beans, to a depth of one inch, and press the soil firmly around the seed. Place the same number of seed loose in numbers two and five. Number one, two, four and six are to be kept moist throughout the experiment. Fill number five with water, that has been previously boiled and cooled, to keep out air. Place numbers one, three and five in a warm, light place. Place number six in a warm place, but cover it with dark cloth or paper to exclude the light. Keep number three in a refrigerator or ice box so that the temperature may be maintained near the freezing point. Examine the cans after two or three days, and then every day until you can answer the following: Which of these conditions; soil, moisture, warmth, air, light, are necessary for the germination of seeds? Seeds contain a very small amount of air. The water may also contain a small amount of air. Take this into account in answering the questions.

48. PURITY OF SEEDS AND GERMINATION TEST.

(a) Purity of Seeds. Materials: Three samples of clover seed or any small seeds used locally, chemical scales, three blotters of ordinary size, three pans and glass to cover each.

Weigh out 5 grams of samples of seed from each of three samples furnished. Spread this on a sheet of paper.

Separate into three piles: (1) Chaff, dirt, broken seed, etc.; (2) Sound seed; (3) Weed seed. Weigh each lot. Save the seed from each sample. Record results.

Sample	Weed seed, grams	Chaff, dirt, broken seed, grams	Per cent of sound seed	Market price per lb.	Actual cost per lb.
1					
2					
3					

Which gives the largest amount of seeds for the price? Does this sample contain many weed seeds? Considering price, quality and weeds seed, which sample should be purchased?

(b) Germination Test. Moisten a piece of blotting paper and lay it in a pan. Take 100 seeds from a sample of pure seed just as they come. Put them on the blotter and label. Moisten another piece of blotting paper and lay over them, and cover with glass or straw. Keep moist and in a moderately warm room. Do the same with the other samples. Examine from day to day, and remove the sprouted seeds from each sample.

Sample No.	3 days	4 days	5 days	Total per cent germinated
1				
2				
3				

The quickness with which the seeds start indicates something of their vigor. Which sample germinated quickest? From this and (a) fill out the following table:

Sample No.	Market price per lb.	Per cent of good seed	Cost per lb. of good seed	
1				
2				
3				

49. PLUMP AND SHRUNKEN SEEDS.

Materials: A box about 4 inches high, a foot wide and 2 feet long. Half pint sample of wheat seed and scales.

(a) Calculation of Plant Food in Seeds. Weigh 100 plump, well-formed wheat seeds. From this weight and the following data compute the grams of nitrogen, phosphoric acid, and potash per 1000 wheat seeds. Wheat contains about 2 per cent nitrogen and 90 per cent dry matter. The dry matter contains about 2 per cent ash, about 50 per cent of this ash being phosphoric acid and 33 per cent potash. Repeat the experiment, using 100 shrunken seeds.

(b) Growth of Plump and Shrunken Seeds. Select 12 plump seeds and also 12 that are shrunken. Fill the box with good rich, moist, loamy soil. Plant the plump seeds in one end and the shrunken seeds in the other. Keep the soil moist and warm. Examine the young plants from time to time as they germinate and grow. Note the number of plants secured from the plump seeds and from the shrunken seeds. Let the plants continue to grow for several weeks.

Questions: Can you detect any difference in the hardiness of the plants and the amount of plant material produced by the two grades of seed? State your conclusions.

50. DEPTH OF GERMINATION.

Materials: Three half-gallon fruit jars, three pint fruit jars.

(a) Large Seeds.—Place about 1½ inches of good moist soil in the bottom of each jar. Plant one with peas,

one with beans, one with corn, as follows: Plant two seeds near together against the wall of the jar and on the surface of the soil. Add an inch of soil, press it down firmly and after turning the jar slightly to one side, plant two more seeds so that they will not be directly over those already planted. Continue to add soil and plant seeds every inch up the side of the jar till near the top. Wrap each jar in dark cloth or paper to exclude the light, and set in a warm place. From day to day, remove the wrapping from the jars and note the growth, recovering them immediately. This exercise should give some idea of the power of different kinds of seeds to force their plantlets up through the soil. Note the depth of the lowest seed in the jars that is able to penetrate to the surface.

(b) Small Seeds.—Repeat (a) using the pint jars and planting the lowest seeds about an inch from the bottoms. Use small seeds, such as radish, alfalfa, clover.

How do the depths of germination with large seeds and small compare? Give reason for this. Oil producing seeds contain much more food in proportion to their size than do the starchy seeds.

51. OSMOSIS.

Materials: Potato, two wide mouth glasses or beakers, glass tube 6 inches long and about 3-16 inch inside diameter, egg, hatpin, sealing wax, salt.

1. Pare a potato and cut slices from it. Place some of these in water and some in a strong solution of salt made by placing a small handful of salt into a glass of water. Examine at the next exercise.

2. Cement with sealing wax to the smaller end of an egg a piece of glass tubing about 6 inches long and about 3-16 inch inside diameter. Clip away part of the shell from the larger end of the egg, place in a wide mouth bottle or small beaker full of water and then carefully pierce a hole through the upper end of the eggshell by pushing a hatpin through the glass tube. Examine at the next exercise.

In the case of the potato the piece in water is plump and rigid, which shows that the water passed into the potato faster than the sap passed out. The piece in the salt solution is wilted, which shows that the salt solution did not pass into the potato as fast as the sap passed out.

In the case of the egg, the water passed into the egg more readily than the denser egg solution passed out into the water. As the water passed in, the egg albumen was pushed up the tube by osmosis. Whenever a plant or an animal membrane separates two solutions, there is an interchange of the two. The less dense the solution, the more rapidly the water passes through the membrane. The solutions of root-hairs are more dense than the soil solutions, hence more water passes into the root than passes out into the soil.

Questions: 1. What is the danger in using an extremely strong fertilizer? 2. How does this experiment show that an excess of alkali in the soil often prevents the growth of the plant?

52. THE WORK OF LEAVES.

Materials: Two small watch glasses, vaseline, two circular disks of two pins.

1. **Transpiration.** Fasten two small watch glasses, one on each side of a leaf of a plant growing vigorously out of doors. The glasses may be held in place by sealing the margin of each all the way around by vaseline or grafting wax. An hour later or at the next meeting examine the drops of water inside of each glass. The giving off of moisture by the leaves is called transpiration.

2. **Light.** Select some leaves on a vigorously growing plant. Shut off the sunlight from parts of the selected leaves, which must be left on the plant and as little injured as possible, by pinning circular disks of cork loosely on opposite sides of each leaf. Two or three days later remove these leaves and the cork disks. Compare the color of the covered area with the color of the remainder of the leaf and explain. Why do most plants not do well in the shade of trees?

3. Oxygen Making. Place some green aquatic plant in a glass jar full of water in front of a sunny window at about 70° F. In a short time note the formation of oxygen bubbles looking silvery by reflected light. Remove to a dark place and after a few minutes examine by lamp light to see whether the rise of the bubbles still continues.

One of the most important facts about life is the taking in by plants from the air of carbon dioxid, a compound composed of carbon and oxygen. The plants use the carbon and give off the oxygen. The process is the opposite in the case of animals, which breathe off carbon dioxid and breathe in oxygen. Plants by a dusty road side often become covered with dust. What effect would this have on 1, 2 and 3?

53. STUDY OF THE CHARACTERS OF BARLEY.*

Materials for this exercise and also for exercises 54 and 55 may be obtained from the University of Nebraska, Department of Field Crops, Lincoln, Neb. For Exercise 53, Order Lot 3. This lot contains nine barley types with about 25 specimens per type. Price per lot $1.75. For Exercise 54, Order Lot 58. This lot contains fourteen species of cultivated grasses given in the exercise, together with one additional. Price per lot $1.75. For Exercise 55 (a) Order Lot 59. This lot contains the seeds of eleven species of clovers given in the exercise with two additional. Price per lot in 2-ounce bottles $1.50. For 55 (b) Order Lot 58, which contains the seeds of the fourteen species of cultivated grasses given in the exercise with one additional. Price per lot in 2-ounce bottles $1.25. One or more lots may be ordered, but the lots will not be broken.

Cultivated barleys include a number of types, or races, and may be classified as follows:

(1) Two-rowed barley.....*Hordeum sativum distichon*
(2) Six-rowed barley.....*Hordeum sativum hexastichon*

The two-rowed barleys commonly grown are characterized by their large, plump grain. In Europe these bar-

*For exercises similar to this on corn, wheat and oats see "Examining and Grading Grains" by Lyon and Montgomery.

leys are used almost exclusively for malting, and hence the name "malting barleys" has come to be generally

FIG. 1. Types of barley spikes: *A*, two-rowed brewing barley; *B*, six-rowed hulless barley

applied to them. However, in America the six-rowed barleys are generally used for this purpose.

The six-rowed barleys include the "naked," or "hulless" varieties, as well as most of our common cultivated barleys. The six-rowed barleys are generally more prolific than the two-rowed, and are most generally grown in this country. The grains of six-rowed barleys are smaller

and not so plump as those of the two-rowed barleys, but are higher in nitrogen.

The varieties of barley are numerous, but only a comparatively few are grown in the United States.

Carefully examine samples of each of the above types of barley including samples of both black and white hulless barley.

Make drawings from a spike of each type, showing the imbricated view.

Note that the berry of ordinary barley is tightly inclosed by the flowering glume, called the "hull," while in hulless barleys the flowering glume and palet do not adhere closely and the berry is free.

In this respect hulled barley is similar to oats, and hulless to wheat.

LABORATORY STUDY OF CHARACTERS.

Typical samples in the spike and of the threshed grain are provided. Carefully describe both the spike and grain of one or more samples of the principal types of barley, as the two-, four-, and six-rowed barleys, and black and white hulless barleys.

The characteristics are obvious enough, so that with a little careful comparison there should be no trouble in finding the proper adjective in the descriptive list.

Use the outline for describing barleys, filling it out carefully.

TERMS FOR DESCRIBING BARLEYS.

Spike

1. Two-rowed (Fig. 1, *A*). / Six-rowed (Fig. 1, *B*). — This refers to the number of rows of grain on the spike.
2. Awned (Fig. 1, *A*). / Partly awned (Fig. 1, *B*). / Awnless.
3. Length (inches).
4. Open (Fig. 1, *A*). / Compact (Fig. 1, *B*). / Crowded. — Has reference to how close or far apart the spikelets are on the rachis.

Shape

1. Tapering toward tip. — When upper spikelets are appressed.
   Tapering both ways. — When spikelets at both base and tip are more appressed than those at middle.
   Uniform (Fig. 1, *A*).
2. Tip tapering (Fig. 1, *A*). — When terminal spikelets are not well filled out.
   Tip blunt (Fig. 1, *B*). — Terminal spikelets well filled out.
3. Base abrupt. — Basal spikelets well filled out.
   Base tapering. — Basal spikelets not well filled out.
4. Sterile spikelets, 1, 2, 3, etc.

Color

1. Whitish.
   Yellowish.
   Yellowish brown.
   Brown.
   Black.

Awns

1. Long (length 5 inches or more).
   Medium (length 3 to 5 inches).
   Short (length less than 3 inches).
2. Parallel (Fig. 1, *B*). — Refers to the relative position of the awns to the head.
   Spreading (Fig. 1, *A*).
3. Deciduous. — This refers to the dropping of the awns at maturity. The awns all drop off on some varieties, while on others they are very persistent.
   Partly deciduous (Fig. 1, *B*).
   Persistent (Fig. 1, *A*).

Color

1. Whitish.
   Yellowish.
   Brownish.
   Black.

Spikelet

(This is not a spikelet in the botanical sense, but really a mesh of three spikelets.)

1. Number grains per spikelet (1, 2, 3).
2. Number of sterile flowers. (Refers to sterile flowers in a spikelet.)

Size

1. Broad (Fig. 2, *C*). — This depends largely on the shape of the grain and how well it is developed.
   Medium (Fig. 2, *B*).
   Narrow (Fig. 2, *A*).

Outer Glume. (In barleys these are very narrow and pointed.)

1. Awned (Fig. 2, *B*). — The outer or empty glume should not be confused with the flowering or seed-bearing glume.
   Awn-pointed.
   Awnless (Fig. 2, *D*).

Grain

1. { Inclosed in flowering glume. / Free (naked). } This is the distinguishing characteristic between the naked or hulless barley and the ordinary kind. In the latter the grain is so tightly inclosed that it is not freed in threshing.

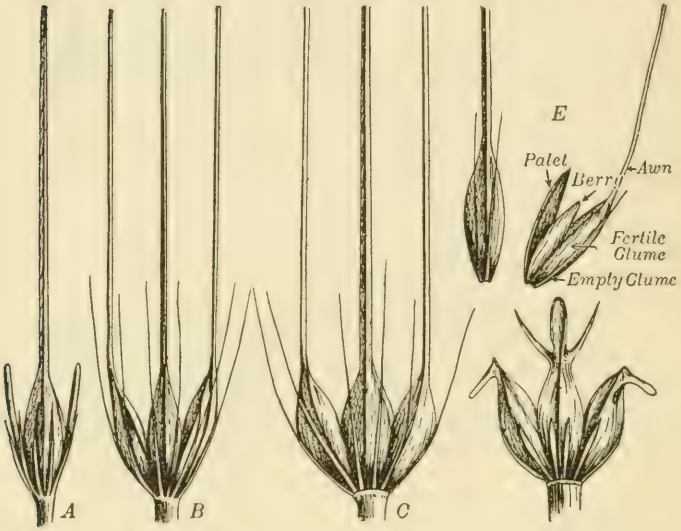


FIG. 2. Types of barley spikelets: *A*, spikelet from two-rowed barley; *B*, spikelet from six-rowed barley; *C*, a six-rowed hulless barley; *D*, a white hulless and awnless barley; *E* shows a barley spikelet torn apart.

2. { Hard. / Medium. / Soft. } This point is most easily determined by biting or cutting the grains and comparing with standard samples.

Shape

1. { Long. / Medium. / Short. } Different varieties of barley show considerable variation in size and ratio of length to diameter. Pick out about six typical grains to examine for these points.

2. { Thin. / Medium. / Plump.

Crease

1. Deep. / Medium. / Full. — Cut cross sections of several typical grains.

Cross section

1. Horny. / Dull. / Starchy. — This point is determined by making cross sections and examining carefully. Where only part of the grains show one characteristic and the rest some other, the per cent of each kind should be expressed.

Color

1. Black. / Purple. / Purplish. / Brown. / Yellowish. / Whitish. — When black hulless barleys are fully matured they are purplish black in color, but when cut very green they are often a yellowish white in color, with only a tinge of purple.

Weight of 100 grains.....grams

OUTLINE FOR DESCRIBING BARLEYS.

Spike

1 .....
2 .....
3 .....
4 .....

Shape

1 .....
2 .....
3 .....
4 .....

Color

1 .....

Awns

1 .....
2 .....
3 .....

Color

1 .....

Spikelet

1 .....
2 .....

Size

1 .....

Outer Glume

1 .....

Grain
1.....
2.....
Shape
1.....
2.....
Crease
1.....
Cross section
1.....
Color
1.....
Weight of 100 grains (grams)

Question: What advantage has hulless barley? Hull barley?

54. OUTLINE FOR DESCRIBING GRASSES.

Materials: Lens. See Exercise 53.

The following outline is used in the study of common cultivated grasses. By following the outline one's attention is called to the distinguishing characteristics of each kind, giving not only a means of identification but a good knowledge of the grass.

The stem and leaves
Height .....
Color of stem.....
Color of leaves.....
Number of leaves.....
Head
Awned or awnless.....
Panicled, compact, or spiked.....
Size (give length and diameter).....
Color of awns.....
Color of chaff.....
Root
Does it spread from rootstocks?.....
Is it a sod-forming or bunch grass?.....
Seeds
Size (give average length in inches).....
Color (general color).....
General Notes
Is seed free or inclosed in scales?.....
Weight per bushel.....
Amount sown per acre.....
Vitality .....

Drawings of Seeds. Make drawing from convex side. Make drawing of cross section.

Question: Give an illustration of a sod forming grass and a bunch forming grass. Discuss the advantage of each.

55. IDENTIFICATION OF CLOVER AND GRASS SEEDS.

Materials: Lens. See Exercise 53.

There is no work which requires more careful attention or is more valuable than the identification of grass and clover seeds, and separating them from their adulterants.

For examining the seeds a small lens is very useful. Use the following artificial key, which is not intended to describe the seed but simply calls attention to the most prominent characteristics of each variety. It is much better to first learn to identify by use of the key than by use of the drawings.

(a) Key for Identification of Clover Seeds

Seed free (not inclosed in pod)
- Seed bean-shaped
  - Color, pinkish, ⅛ in. long ..... Crimson Clover
  - Color, mostly yellow; large seeds are kidney shaped ..... Alfalfa
    (Turkestan alfalfa is same, but slate colored.)
  - Seeds larger and more regular than in alfalfa ..... Burr Clover
  - Color, dark yellow to brown ..... Yellow Trefoil
- Seed oval-oblong
  - Color, yellow; seed notched near one end ..... Bokhara Clover
- Seed heart-shaped
  - Color, yellow to brown ..... White Clover
  - Color, dark green to black ..... Alsike Clover
- Seed somewhat triangular
  - Color, yellow to brownish ..... Red Clover

Seed inclosed in pod
- Pod large and corrugated, ¼ in. long
  - Color, brown; seed, bean-shaped ..... Sainfoin
- Pod whitish, ⅛ in. long
  - Color, yellow; seed oval, notched near end ..... Yellow Sweet Clover
- Pod brown, ⅛ in. long
  - Color, dark brown, seed mottled ..... Japan Clover

(b) Key for Identification of Grass Seeds

Seeds distinctly awned
- Seed ¼ in. or more in length
  - Very hairy or pubescent, flat, thin ..... Meadow Foxtail
  - Awns attached at tip ..... Annual Rye Grass
  - Awns long, twisted, attached near base .... Tall Meadow Oat Grass
- Seeds less than ¼ in. long
  - Small brownish seed ..... Sheep Fescue

Short-awned or awn-pointed
- Small, dark brown seeds, very rough near tip .... Crested Dog's-Tail
- ⅜ in. long, smooth, light colored ..... Wheat Grass
- ¼ in. or less in length ..... Orchard Grass

Awnless
- ⅜ in. long or thereabout, nerves very prominent .... Brome Grass
- About ¼ in. long, light brown ..... Note difference in shape and size of rachilla ..... Perennial Rye Grass / Meadow Fescue
- Hard, smooth seeds, about ¼ in. long
  - Dark brown color ..... Johnson Grass
- ⅛ in. long or less
  - Keel rough, sawlike ..... Redtop
  - Keel not commonly rough ..... Kentucky Blue Grass
- Seed free from glumes, polished
  - Very small, 1-32 in. in length, polished ..... Timothy

56. CUTTINGS AND THEIR USE IN PROPAGATION.

The more common forms of artificial reproduction are by cuttings, grafting and budding. A cutting is a detached portion of a plant inserted in soil (or in water) for the purpose of producing a new plant. Cuttings may be divided into three classes: 1. Hard-wood cuttings. 2. Soft-wood cuttings (herbaceous). 3. Root-cuttings.

1. **Hard Wood Cuttings.** A hard-wood cutting is a cutting from the ripened wood of a deciduous plant of the present or previous season's growth. The cultivated plants most commonly propagated by the use of hard-wood cuttings are grape, olive, fig, quince, currant and gooseberry, and many ornamental shrubs, such as privet, tamarisk, hydrangra, etc.

2. **Soft Wood Cuttings.** This class of cuttings is exemplified in the "slips" used to increase the number of roses, carnations, geraniums, fuchsias, begonias, etc. Leaf cuttings are often employed in multiplying begonias, cacti and other plants having thick fleshy leaves containing a

large quantity of plant food. Soft-wood cuttings are of little importance in agriculture.

3. Root Cuttings. Short cuttings of roots may be used in the propagation of many plants, notably the horse radish. The roots of lippia, bermuda grass and some other grasses can be cut into short pieces and planted.

Obtain some hard-wood cuttings of apple, peach, pear, plum, berry canes, fig, olive, quince and any others that are available. Get cuttings about 18 inches long and 3-8 to 5-8 inch in diameter, using wood of the previous season's growth. They should be obtained during the dormant period (January) or at the time of pruning. Cut five from each tree and tie them in separate bundles with the butts all one way, then label with a piece of wood.

In order to save time and trouble we may as well obtain scions for grafting at this time and care for them in the same ways as described below for cuttings. A scion is a portion cut from a plant to be inserted upon another plant with the intention that it shall grow. Obtain scions to be grafted on year old seedlings grown as indicated in Exercise 56. If there are no year old seedlings to be grafted, no scions need be gathered, but in order to save time in getting started seedlings should be bought. Select 10 scions of about the size of the seedlings to be grafted so that they may be easily matched, tie in bundles and label with a piece of wood. Heal in the cuttings (and scions) by digging a trench in moist, sandy, well drained soil in a shady place as on the north side of a building. Place the bundles in the trench in a slightly inclined position and cover all over but the tips, pressing the soil firmly about them.

In February or March, when the nursery is ready, dig up the cuttings and plant in nursery rows, making the rows 2 feet apart for hand cultivation or 3 feet apart for horse cultivation and plant the cuttings 8 inches apart in the rows.

Only berries, fig, olive and quince are raised by cuttings, but for the sake of experiment and practice try cuttings of the others.

57. ESTABLISHING A DECIDUOUS ORCHARD.

The operations involved in the establishment of a deciduous orchard are as follows:

1. Collection of Seed. When seeds are to be collected on a large scale it is usual to get them from some cannery, but when only a few are desired they may be obtained in any convenient manner. As seeds planted seldom come true to types, all plantings of seed must be made with the knowledge of the kind of scions that are to be grafted or buds to be budded on the young seedlings. For instance, it is customary to make combinations about as follows: Peach budded on peach, preferably on strong growing yellow peach seedling. Pear, budded or grafted on pear, preferably on Keiffer pear. Apple grafted on apple. By root grafting onto roots of the Northern Spy apple, trees obtained are said to be immune from attacks of the Woolly Aphis. Plum or prune budded on peach in moist, sandy loam soils. Plum budded on Myrobolan when subject to overflow, standing water, or on heavy soil. Apricot, same as plum. Walnut grafted on California black walnut. Quince, olive and fig are grown from cuttings.

After the seeds are collected keep them in a cool dry place, but not in an air-tight receptacle. Obtain at least five seeds of each fruit to be propagated and ten of the smaller kinds as they are more likely to be lost.

2. Stratification of Seed. In January obtain some cheesecloth and cut into squares of about a foot each, making twice as many squares as you have sets of seeds. Moisten all the cloths with water. Take the seeds previously collected and select a spot in the garden, preferably one in sandy soil. Dig a hole a foot square and a foot deep. In the bottom spread out one of the cloths and place on it any set of seeds; then over them place another cloth and two inches of soil. Place another cloth, seeds, cloth, and soil, in the same way until all the seeds have been stratified. Record in your note book the various strata. Of course if there are more than five sets of seeds to be stratified the hole must be deeper than a foot or prefera-

bly, dig two holes rather than go beyond a foot deep. Place a stake by the seeds with your name on it so that they may be readily located. Allow the seeds to remain in the ground about six weeks.

3. **Transplanting to the Nursery.** The best location for a nursery is on loam or sandy soil, but trees may be successfully grown in less favorable soil. The land should be plowed deep and thoroughly cultivated. By the use of string and stakes dig with a hoe a trench the desired length. No definite depth can be given for planting the seeds, but the smaller ones such as pear or apple should be planted one and one-half inches deep, while the larger ones like the peach or apricot two inches deep.

Carefully dig up the stratified seeds and take them to the nursery taking care not to injure the young sprouts. Plant them in rows about six to eight inches apart. The rows should be about three and one-half feet apart for horse cultivation, but for hand cultivation two feet is sufficient. Plant only the sprouted seeds. Mark with stakes the location of each set of seeds. The stakes should be uniform in size and, if desired, painted white. A convenient size for stakes is 1x2x24 inches.

4. **Stripping the Young Seedlings.** By the following summer it will be found that the small branches have grown down close to the ground. In order to facilitate the operation of either budding or grafting it is necessary to break off with the fingers the young limbs close to the ground and up to a distance of five or six inches, according to the size of the tree. Nothing else need be done to the trees the first summer, but of course the ground should be well cultivated, weeds kept down and irrigation practiced according to local conditions.

5. **Grafting and Budding.** Grafting. Where grafting is to be done the scions of the desired varieties should be secured when the trees are pruned in December or January. Care for the scions and insert them as described in Exercise 56. Budding. What is commonly called "June Budding" is usually practiced in California in April or May. The bud is inserted close to the ground in

either of these months. In selecting the bud go to some tree that produces the desired variety of fruit and cut off a few vigorous growing limbs. Carry limbs and all to the nursery and then cut and insert buds as described in Exercise 59.

6. **Heading Back to the Bud.** After the bud has grown into a branch from four to six inches long, head back to the bud by cutting with a sharp knife the main stock completely off just above the bud. (Fig. 11c).

7. **Digging the Nursery Trees.** The following February the trees will be about two years old from the seed, but the age of a tree is not reckoned from the time of planting the seed, but from the time of inserting the bud or graft. Our trees are therefore considered as one year old. (Large nurserymen often obtain one year old seedlings from France at a low cost, thus saving a year's time.)

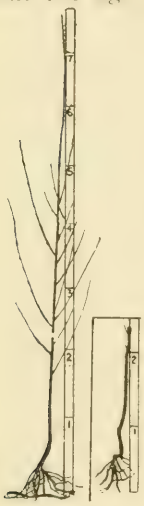


Fig. 3.

In February dig the trees from the nursery rows so as to obtain a large number of small branching roots. (Previous to digging, the orchard should be made ready to receive the young trees as described in Exercise 60.) In lifting from the nursery, digging with a well-sharpened spade, which will sever the long roots cleanly, is perhaps the best method. The tap root cuts no figure in California orchard planting, but it is important to have as many small lateral roots as possible. Any broken roots should be clipped off. Do not permit the roots after lifting, to dry out. Cover them with wet sacks or wet straw unless they are to be planted immediately.

If trees after digging are not to be planted the same day they may be kept by being "healed in." To heal in, dig a trench in light, moist, but well drained soil; put the trees in singly, side by side, laying the tops all one way, then shovel the earth over the roots until they are well

covered with loose soil. Be sure the soil sifts down well between the roots.

This is the way to care for trees received from any nursery if they are not to be planted at once. In removing from the trenches be sure the roots do not dry out. Directions for planting are given in Exercise 61. The trees should be cut back to 18 inches just before planting as shown in figure 3.

58. GRAFTING.

Materials: Grafting knife or medium large pocket knife with sharp blade, saw, thin chisel or grafting tool (Fig. 5) or screw driver, 2 quart pail, round paint brush about three-fourths inches in diameter, grafting wax prepared as follows: In the pail place one pound of resin, one pound of beeswax and one-half pound of rendered tallow (obtained by melting beef tallow and allowing it to cool.) Thoroughly melt, stirring occasionally with the brush. Waxed string. Before removing the melted grafting wax from the fire place into it a ball of No. 18 knitting cotton. Leave it in the wax for several minutes, turning frequently. Remove from the pail and allow to drain and dry.

Were all forms of the art of grafting to be taken from the horticulturist today, commercial fruit growing in its high state of perfection would decay with the orchards now standing. All the common pomaceous fruits (apples and pears), the stone fruits (peaches, plums, cherries and apricots), and citrus fruits (lemons and oranges), are now multiplied by grafting and budding. The progress in plant breeding and the great rapidity which new sorts are now distributed could not be obtained without the aid of budding or grafting. Under the existing conditions it is not necessary for the originator of a new sort of apple to give any thought to the question of fixing that type so it may be reproduced by seed. Grafting and budding has settled that long ago.

(a) Whip Grafting. This style of grafting is the one most universally used. It has the advantage of being

well adapted to small plants only one or two years old. Also it may be used on seedlings standing in the nursery or on seedlings or roots dug up and the work done on a bench.

1. Grafting Seedlings in the Nursery. The stock is the plant or part of it upon which the bud or scion is inserted, in this case the seedling trees. Make the graft by cutting the stock off diagonally just above the ground. Make one long smooth cut with a sharp knife, leaving about three-fourths of an inch of cut surface as shown in figure 4, a. Place the knife about one-third of the distance from the end of the cut surface, at right angles to the cut, and split the stock in the direction of its long axis. Cut the scion with about three buds, then cut the lower end as shown in figure 4, b, so that when the stock and scion are forced together as shown in figure 4, c, the cut surface will fit neatly together and one will nearly cover the other if the stock and scion are of the same size. The importance of having an intimate connection between the growing tissues (the cambium layers) of both stock and scion, cannot be too strongly emphasized, for upon this the success of grafting depends. A difference in diameter of the two parts to be united may be adjusted by placing the scion so that the cambium layers meet on one side only, but it is desirable to have stock and scion nearly the same size if possible.

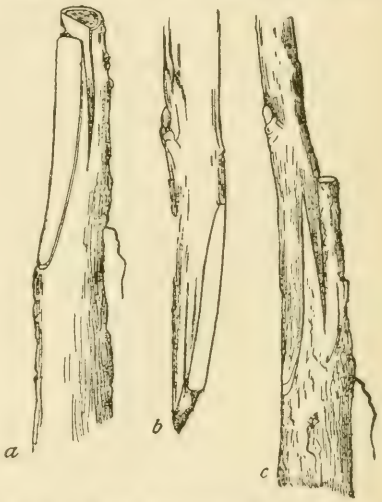


FIG. 4.—*Whip grafting;* a, *the stock;* b, *the scion; c, stock and scion united.*

After the parts have been forced together, tie them with waxed string, then coat with grafting wax.

2. Grafting Seedlings not in the Nursery. Root Grafting. This is the prevailing Eastern method and is not so much in use in California except for root grafts on Northern Spy apple stock. Cut the scion with about three buds as before and cut the stock about as long as the scion. If the roots are to be used cut them into lengths of about five or six inches.

The stock and scions are obtained in the fall or in December and stored until February or March, when grafting can be done. They may be packed away in moss, sawdust, or in sand or healed in, in the usual way. (See Ex. 56.) In the spring when setting out in the nursery, set the root graft just below the surface of the ground and the seedling graft just above the surface.

Cleft Grafting. This style of graft is particularly adapted to large trees when for any reason it becomes necessary to change the variety. Branches too large to be worked by other methods can be cleft grafted. Saw off a branch to be grafted, being careful not to loosen the bark from the portion of the stub. Split the exposed end with a broad, thin chisel or grafting tool or hatchet, (fig. 5). Then with the wedge-shaped prong at the end of the grafting tool or with a hatchet or even a screw driver, spread the cleft so that the scions (fig. 6, a) may be inserted (fig. 6, b.) The scion should be of the previous season's growth and should be long enough to have two or three

FIG. 5.—*Grafting tool.*

buds. Cut the lower end, which is to be inserted into the cleft, into the shape of a wedge, having the outer edge thicker than the inner (fig. 7.) Cut a scion so that the lowest bud will come just at the top of this wedge, so that it will be near the top of the stock. The advantage of cutting the wedge thicker on one side is illustrated in figure 7, which shows how the pressure of the stock is brought upon the outer growing parts of both the scion and the stock, whereas were the scion thicker on the inner side the conditions would be reversed, and the death of the scion would follow. To make the contact of the growing portion doubly certain, set the scion at a slight angle with the stock into which it is inserted in order to cause the growing portions of the two to cross. After the scions have been set, complete the operation of cleft grafting by covering all cut surfaces with a layer of grafting wax. In case both scions "take," after a good growth of leaves has appeared, cut off evenly at the stock the scion which appears the weaker. Wax the cut place. Only one should be allowed to continue growing.

FIG. 6.—*Cleft grafting;* a, *the scion;* b, *scions inserted in cleft.*

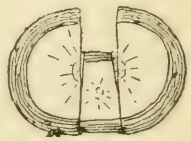


FIG. 7.—*Cross section of stock and scion.*

59. BUDDING.

Material: Budding knife, but a medium or a large sized pocket knife will do if sharp, and raffia.

There are numerous styles of budding, but only the one in most common use will be described. Budding is one of the most economical forms of artificial reproduction and each year witnesses its more general use. It is economical in the amount of wood used from which to take buds. In this method a single bud does the work of three or more upon the scion used in grafting. The operation of budding is simple and can be done with great speed by expert budders. Budding may be done from May to September. The usual plan is for a man to set the bud and a boy follow closely and do the tying.

FIG. 8. — *A bud stick.*

(a) The Bud.—Obtain buds from wood of the present season's growth. The work of budding is done during the season of active growth. Prepare the bud stick so that the petiole or stem of each leaf is left attached to serve as a handle to aid in pushing the bud home when inserting it beneath the bark of the stock. This is what is usually called a shield bud and should be cut so that a small portion of the woody tissue of the branch is removed with the bud. A bud stick is shown in figure 8. The operation of cutting the bud is illustrated in figure 9. The stock for budding should be at least as thick as an ordinary lead pencil.

(b) The Operation.—The height at which buds are inserted varies with the operator. In general the nearer the ground the better. Make the cut for the insertion of the bud in the shape of the letter T (fig. 10, a). Usually the cross cut is made not quite at right angles with the body of the tree, and the

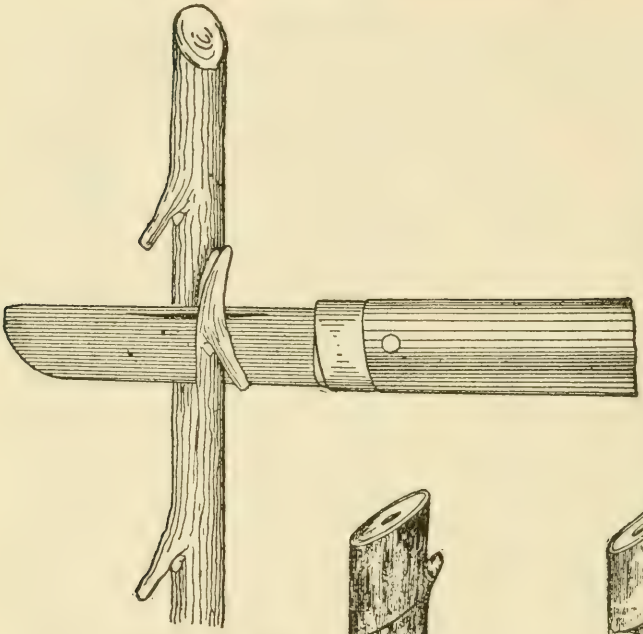


FIG. 9.—*Cutting the bud.*

FIG. 10.—*Budding—preparing the stock.*

stem to the T starts at the crosscut and extends towards the root for an inch or more. The flaps of bark caused by the insertion of the two cuts (fig. 10, b) should be slightly

loosened with the ivory heel of the budding knife, and the bud, grasped by the leaf stem as a handle, placed under the flap and firmly pushed into place until its cut surface is entirely in contact with the peeled body of the stock (fig. 11, a). Raffia is then tightly drawn about, above and below the bud to hold it in place until the union shall be formed (fig. 11, b). Bands of raffia about 16 or 18 inches long make a most convenient tying material. As soon as the buds have united with the stock, the raffia should be cut in order to prevent girdling the stock. This done, the operation is complete until the following spring, when all the trees in which the buds have "taken" should have the tops cut off just above the bud (fig. 11, c). The removal of the top forces the entire strength of the root into the bud, and since the root itself has not been disturbed by transplanting, a more vigorous growth usually results from the bud than from scions in whip grafting when the roots are disturbed.

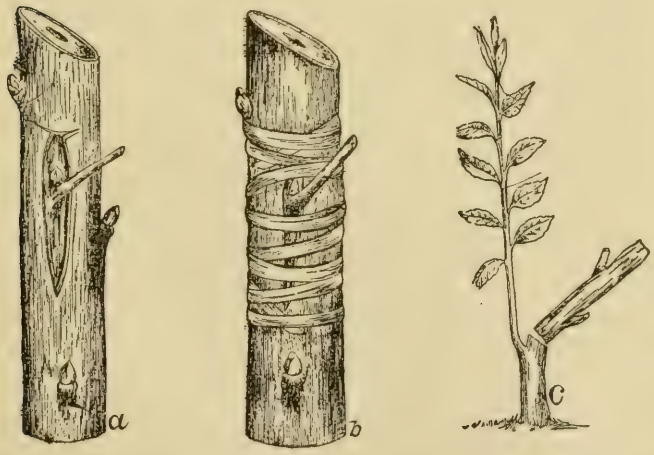


FIG. 11.—*Budding;* a, *inserting the bud;* b, *tying;* c, *cutting off the top.*

60. LAYING OUT AN ORCHARD.

In laying out an orchard it is necessary to have one side and one end of the field at right angles. Often there are regular subdivisions to work from; but, if there are none, these two lines, called base-lines, may be established with a transit. If the base-lines cannot be established in any other way, proceed as follows to find a square corner. Begin at the corner stake and measure off 60 feet along one line with a steel tape, and put in a stake. Then from the starting point measure off 80 feet as nearly at right angles with the first line as can be judged with the eye, and describe an arc of several feet, holding one end on the corner stake. Then from the 60 foot mark measure diagonally across to a point on the arc that is 100 feet from the 60 foot mark and set a stake there. The three stakes will then form a square corner. The distances 30, 40 and 50 feet would do as well, if your tape is only 50 feet long.

There are two methods of planting, the square and the equilateral triangle, but as the square method is the one in general use, this method alone will be described.

Make at least thirty stakes about half an inch square and one foot long. These may be split out of redwood or pine. (If six inches of the end of each is dipped in whitewash they can be readily seen, and should any of the stakes be out of line it will be noticed at once.)

Obtain a piece of No. 10 gauge galvanized wire; and, if the trees are to be 20 feet apart, the wire should be 202 feet long; if 24 feet apart 242 feet long, etc. Attach to each end of the wire a three-inch iron ring by bending the wire. Not over a foot from the original end of either end of the wire, wrap a piece of small wire, making three laps and solder into place.

In the same way solder into place a small piece of wire every 20 feet along the wire if the trees are to be 20 feet apart. In handling the large wire be careful not to get a kink in it as it can be easily broken in this way.

Having established base-lines, place a stake in each corner of the field, set stakes for ten trees for each stretch

of the wire by stretching the wire along one of the base-lines. Having set the stakes along the outside line, start at the same end of the field again, and set another line of stakes, parallel with the first and the length of the wire (chain) from it. Follow out this method until the entire field is laid out in checks. With the check lines established it is only necessary now to set stakes at the 20 foot marks on the wire where the trees are to be planted.

61. HOW TO PLANT A TREE.

Materials as described in experiment. Make a tree-setting board out of a piece of pine one inch by 4 inches by four feet long. About an inch from each end of the board, bore a hole an inch or so in diameter. Then saw a triangular notch in the middle of one side of the board, making the notch about one inch across and one and one-half inch deep.

Make two stakes small enough to be driven through the holes, and a foot in length. Place the notch against the stake where the tree is to be planted and push the stakes through the holes into the ground then remove the center stake and board. Dig a hole not less than eighteen inches in diameter and eighteen inches deep. After the hole is dug, replace the board over the end of the stakes and plant the tree with the trunk resting against the center notch. In setting out the tree, one person should hold the tree in an upright position against the notch while another shovels or fills in loose soil around it, first spreading out the roots and rootlets in as natural position as possible. The surface soil should be put in first among the roots taking care to fill every interstice, thus bringing all the roots in direct contact with the soil. When the hole is two-thirds full, firm the earth thoroughly about the roots, but before doing this draw the tree up to its permanent position. The top three or four inches should not be tramped unless the ground is wet from recent rains. Scoop a basin out around the tree which will hold at least ten gallons of water and apply water either by bucket or irrigation. The following day draw

in loose soil and fill up the basin. From a soil mulch by reducing this top soil to as fine a condition of tilth as possible. Guard against setting too deeply, but allow for the settling of soil so that when once established the tree will stand about as it did at the time of removal from the nursery.

62. PROPAGATION OF THE GRAPE.

The prevailing method of propagating the grape is by growing from cuttings.

There are two distinct types of vineyards. We may establish a vineyard on its own roots; or establish a vineyard on resistant roots.

(a) VINEYARD ON ITS OWN ROOTS.

1. Securing the Cuttings. A good cutting consists exclusively of one-year old wood; that is, wood which has grown the previous season. The cuttings can be secured during the winter pruning (January), when the vines are dormant. In a moist soil in a cool region they should be about sixteen inches long but in drier regions about twenty inches long. It is not possible to make all cuttings exactly the same length because they should terminate at each end at a node. Cuttings should be from three-eighths to five-eighths of an inch in diameter. Take great care not to injure the bud at either terminal. Cut off all intermediate buds. Cuttings from the outer ends of long canes are not so likely to root.

2. Care of Cuttings. Cuttings should be kept dormant until the time comes for setting them out. This may be done by tying them in bundles of convenient size, in this case put fifty in a bundle. After labeling by means of a stick of wood tied to the bundle, dig a trench as deep as the length of the bundles on the north side of a tight board fence or shed, making the trench wide enough to receive them. Place them in it in a nearly upright position and cover with loose earth and on top put some straw. They should be in moist but not wet ground as too much moisture rots them.

3. Planting the Cuttings. The cuttings can either be planted in the field or in the nursery. If they are to be planted directly in the field, planting may be done the following March as described below. Owing to the fact that only from 50 to 80 per cent of the cuttings will take root, or form vigorous roots, it is usual and far more desirable to transfer the cuttings to the nursery in March, allowing them to take root and remain there one year. (This is the method we shall pursue.) At the end of that time only vigorous rooted cuttings need be used and thus a much more perfect stand in the vineyard can be obtained. In planting in the nursery rows, make the rows four feet apart for horse cultivation and two feet apart for hand cultivation, in either case planting them three to four inches apart in the rows. The nursery should be in loose, moist soil so that a good root system will develope. Leave the upper bud just above the surface of the ground.

4. Transferring to Vineyard. A year later when planting in the vineyard it is customary in heavy soils to plant 8 by 8 feet apart, but in light soils 12 by 12 feet apart, laying out the vineyard the same as an orchard. Dig the holes the width of a spade and the length of the cutting in depth. Leave the top soil to one side so that it can be put into the hole first when filling.

When all or a part of the holes are dug, dig up the cuttings and if not very moist place them in water for at least 24 hours; otherwise transfer directly to the vineyard after digging and plant as soon as possible—in any case the same day, but before planting trim the roots back to from 2 to 3 inches. In planting place a cutting in a hole and shovel in the top soil first so that when the cutting is leaning against the side of the hole there will be one bud just above the surface of the ground when the filling is complete. Continue filling the hole until it is about half full, then tramp down with the foot. Continue filling the hole so that when the hole is completely filled the bottom soil is on top. Again tramp down the soil about the cutting and finally leave a soil mulch over the entire area covered.

b. VINEYARD ON RESISTANT ROOTS.

American wild vines are characterized by marked differences in degree of resistance to Phylloxera, a very destructive insect. By selection a few wild types have been secured that are almost immune to the attacks of this insect. For a deep soil Rupestris St. George is used as the stock; for dry soils or on hill sides Reparia x Rupestris 3309. The disease does not spread much in sandy soil so that it is advisable to establish the vineyard on its own roots in this case.

A resistant vineyard may be established in either of two ways: 1. By Field grafting; or 2. By Bench grafting.

1. Field Grafting. This may be accomplished by planting resistant cuttings directly in the vineyard and field grafting, or grafting in the field the following winter. Only a 50 to 80 per cent stand can be obtained by this method, hence it is not in favor.

2. Bench Grafting. Secure cuttings from resistant vines such as Rupestris St. George or Reparia x Rupestris 3309 during the dormant period, or at the time of pruning (January.) If necessary secure these cuttings from a nurseryman. Likewise secure scions from the desired varieties to be propagated. The scions may be any convenient length—two or three feet. Select both cuttings for stock and cuttings for scions from strong growing healthy vines. They should be of the same size to be accurately matched in grafting. Heel them in until some convenient time in late winter or early spring (March), then dig them up and graft. (The work is usually done on a bench, hence the name "bench grafting.") The scions should have one bud and should be long enough to handle while grafting—two or three inches. Do not tie with raffia or use grafting wax. Keep the grafted stock in bundles of convenient size in moist sand in a warm place, or preferably in a warm room when a callus will form at each joint. A month later they may be planted in the nursery. The following spring transfer to the vineyard. In planting any kind of rooted vines prune the roots to

two or three inches in length at the time of planting. This method of establishing a vineyard is the accepted French one and has proved successful in California.

63. PROPAGATION OF THE ORANGE.

(The following applies to the lemon and pomelo as well as to the orange.)

The propagation of the orange differs considerably from the propagation of deciduous trees.

1. Selecting and Planting the Seed. Select seeds from the sweet orange, Florida sour orange or pomelo with which to grow the stock. Plant the seeds in a seed bed sheltered by a lath house or in the open, but in either case the seed bed should be well drained, mixed with a light soil and mulch and finally covered with a layer of light sand. In preparing in spring plant the seeds an inch deep and 1½ inches apart.

2. Digging the Seedlings. One year later remove the seedlings to the nursery, planting them in rows. The rows should be about 39 inches apart for horse cultivation, but for hand cultivation 16 inches is sufficient. In either case plant the trees about one foot apart in the rows.

3. Budding the Seedlings. The seedlings should be budded after being in the nursery either one or two years. A week or two before the operation, strip the seedlings by removing all leaves and thorns from the lower six inches of the trunk to make room for the bud. Insert the bud two or three inches above the ground. The best time to bud is in the spring. Budding may also be done in midsummer or in the fall. The growth from the summer buds is likely to be killed by frost during the first winter. Fall buds lie dormant during winter and start the following spring. When the bud attains 6 to 8 inches growth, remove the top of the tree as shown in figure 11, c.

4. Transferring to Orchard. After one or two years the trees should be transferred to the orchard. The most common method is to "ball them," that is, to remove a ball of earth with the roots, tying a sack around them to keep the soil from falling away.

The usual method of planting is in squares. The trees should not be less than 20 feet by 20 feet apart.

64. PRUNING FRUIT TREES, VINES AND BUSHES.

To know how to prune the various fruits, we must know upon what kind of branches each bears its fruit and the age of the branches.

The Age of Branches. Take a pear branch and, beginning at the tip, follow it back until you find a point where there is a slight bulge and many tiny scars. This marks the end of one year's growth and the beginning of another. Follow on down the branch and determine its age. In most cases, the age of a branch of a fruit tree can be determined in this way. With many of the vines and bushes these rings are lacking, or are not so noticeable, and the color and condition of the bark is a better guide.

The Pear—fruit bearing habit. The short branches bearing the fruit are called fruit spurs. What are the ages of the various parts of the main branch which bear the spurs? The spurs are each one year younger than the branch upon which they are borne. Why? If an unbranched spur produces a fruit this year, it also produces a vegetative bud at the base of the fruit, which next year continues the growth of the spur and produces a fruit bud in the fall. This causes the zigzag growth characteristic of pear and apple spurs.

Draw a pear spur and a portion of the main branch, showing:

1. Annual ring of growth.
2. Fruit scars.
3. Fruit.
4. Vegetative bud.

How old is this spur? What is the oldest wood on the branch having fruit bearing spurs? The youngest?

Pruning. It usually requires two or more years for a young branch to produce fruit; such a branch may bear fruit for many years. As a branch grows out year after year, the fruit bearing area moves out also, the older parts

ceasing to produce. If we head back a branch, the fruiting area cannot be renewed until new branches are formed.

A fruit spur may change its function and become a branch, which in time may produce new fruit spurs. If we prune away too much foliage bearing wood, the tree restores the balance by changing spurs to branches. Examine branches and find examples of this.

If we cannot head in and must avoid excessive pruning, how, then, should we prune the pear?

The Apple. The fruit bearing habit of the pear and apple is practically the same. Examine an apple branch and prove this.

The Peach—fruit bearing habit. In this case the fruit is not borne on spurs, but directly on one-year-old branches. Occasionally these branches are so short as to look like spurs. On a branch which has grown this season, find a single node which has produced three leaves; carefully remove the leaves and study the buds in their axes. Next spring the two outer ones will try to produce flowers and the middle one leaves.

Notice the following: (1) Wood older than one year bears no fruit. (2) The fruit is borne on the middle and lower portions of one-year wood. (3) Only vigorous one-year wood produces fruit in quantities. (4) The upper buds tend to produce branches. (5) Compare the buds on this season's wood with what came from the buds on last season's wood. Draw a branch which has grown this season (first removing the leaves) and indicate the nodes at which fruit buds are being formed.

Pruning. To produce fruit, we must have a vigorous growth of new branches each year. How may we prune the peach to secure this?

The Cherry—fruit bearing habit. In the cherry we have fruit borne similar to the pear, and also similar to the peach, that is, we find some fruit on one-year wood and some on fruit spurs. Near the base of this season's wood you will find single buds that are more plump than those further up the branch; these will bear fruit next year. There is no foliage or vegetative bud at this point,

so that the lower portion of the branch remains bare after the fruit is picked. The side branches are all grouped on the upper part of the year's growth. The age of a cherry tree can frequently be told by counting these groups of side branches.

Pick off a spur and notice that its growth has been straight, and not zigzag, as in the pear. The central bud of the cluster is a foliage bud and continues growth year after year. It is more pointed than the surrounding fruit buds. What is the age of the oldest branch that you can find bearing fruit spurs?

Pruning. Only a very small amount of the fruit is borne on one-year wood. It is the fruit spurs which are important. With this point in mind, how would you prune the cherry?

Picking Fruits which Possess Fruit Spurs. If a spur is broken off, there are no buds left to renew it. In picking, the fruit should be separated from the spur. Many cherry trees become unproductive because the pickers have broken off the clusters of cherries and thus removed the spurs.

The Grape—fruit bearing habit. The grape is different from both the pear and the peach. In the winter you can find no fruit buds; all buds then are vegetative. In the spring from each bud comes a cane which produces flowers and fruit that same season. Examine a grape cane and verify this. Notice that the fruit is produced usually at the second, third and fourth nodes only, that is, each bud found on the vine in winter tries to produce a cane which will bear from two to three fruit clusters; therefore by limiting the number of buds which we leave on the vines, we limit the number of fruit clusters which the vine will produce. The maximum number of good clusters that a vine will produce ranges from twenty-five to fifty.

Pruning. The grape must be cut back every year so as to have from fifteen to twenty buds only.

Blackberries and Raspberries—fruit bearing habit. These produce fruit on the branches grown this season in the same way as the grape. The first year a straight cane

is sent up, the second year this forms side branches, which terminate in fruit clusters. After the fruit matures the cane dies.

Pruning. How would you prune the raspberry?

(Let the teacher arrange field exercises in winter and prune as many different kinds of fruits as are available.)

65. STRUCTURE AND NATURE OF FUNGI.

Materials: Mouldy bread, (see exercise) dish, lens and compound miscroscope.

The piece of bread furnished has been moistened, a bit of mouldy stable manure placed upon it, then placed in the dish and kept covered for a week.

1. **Mycelium of the Fungus (pl. fungi.)** Examine with a lens, notice the white, mouldy growth—the mycelium of the fungus. It corresponds to the roots, stems and leaves of other plants. It takes its food from the bread.

2. **Sporangium.** Notice that the dark color is due to black specks attached to the mycelium threads by means of a stalk. These are spore cases. Each one is called a sporangium. Some are white. They are the young unripe ones. The spores correspond to seed and the sporangium corresponds to a pod. Mount some of the fungus in a drop of water and examine with the low power of a compound microscope. Make drawings of the mycelium, sporangium and spores.

66. STRUCTURE AND NATURE OF BACTERIA.

Materials: Potato, needle, compound miscroscope. (Let the teacher send to the State Hygenic Laboratory, Berkeley, Cal., and ask for the loan of a box of bacteriological specimens prepared especially for schools. There will be no expense except for express both ways.)

Bacteria are the smallest of all known plants. They are to be found almost everywhere, on the earth, inside and outside the bodies of living animals and plants, in water, in milk, and on the dust particles of the air. Wherever moisture and food are present, some species will grow and multiply hindered only by extremes of temperature,

light, oxygen, or toxic substances. A few are known to cause diseases of man and animals, a rather large number (about 125) are now known to cause diseases in plants.

Some Common Bacteria. Their Structure and Nature. In the material provided, the bacteria are growing on slices of cooked potato exposed to the air of laboratory for three minutes, covered, and then set in a warm place for several days. What conditions favorable to plant growth were provided? Observe:

1. The more or less circular patches of various sizes and colors on the surface of potato—the colonies of bacteria. How can you tell them from molds? Note the difference in form and character of margins of different colonies. Each colony was formed by the multiplication of a single bacterium.

2. Compare different colonies as to nature of the surface, moist, dry, shiny, dull, smooth, wrinkled, etc.

3. Note that some colonies are covered with a skin or pellicle, made up of bacteria stuck together by their gelatinous wall and dried by exposure to air. With needle determine toughness of pellicle.

4. Bacteria feed on substances dissolved from the potato. Some colonies penetrate the potato, others simply pile up.

5. Bacteria, in their growth, produce gases with offensive odors, such as the odor from the potato. The common odors of decay are of this nature. Map the surface of the potato.

6. With the point of the needle touch the different colonies, drawing the needle slowly away. Note that some are viscid, drawing out into long threads as the needle is removed. Clean your needle.

Selecting a colony with wrinkled surface, remove from the smooth, glistening margin a bit on the point of your needle. Stir it into a drop of water on a clean slide. How does it affect the water? Why?

7. Under low power, note the finely granular appear-

ance of the water. Can you make out the individual plants? This power of your microscope magnifies 50 times. Selecting a thin place in the mount turn on the high power and observe:

8. The very small, short rod-shaped bacteria(magnified about 500 times.)

9. In many cases longer rods made up of 2 or more plants fastened. Each plant is a single bacterium. They multiply by the simple division of each plant into two. They may reach their full growth in less than half an hour. Draw.

Make mounts on clean slides from differently appearing colonies. Compare the bacteria from these different colonies as to form, size, etc. Do they seem to be all alike? Are all the bacteria in any given colony alike? (Do not use the same slide more than once without thorough washing and clean your needle each time before making a transfer). Are the bacteria from different appearing colonies always different in form, size, motility, etc.?

PART V—ENEMIES OF CROPS.

67. APPLE SCAB.

Of all diseases of the apple, this is the commonest and best known to the growers. It is the one fungus disease for which they spray. It is world wide, occurring practically wherever the apple is grown. While there is a marked difference in the susceptibility of varieties, all will suffer some under conditions especially favorable to the fungus causing the disease. The scab of the pear is very similar in its symptoms to that of the apple, but is caused by a distinctly different species of fungus, which, however, is closely related to the apple scab fungus. In either case the remedy is the same.

THE DISEASE.

SYMPTOMS. The disease affects the leaves, flowers, fruit and rarely the twigs. It lives over winter on fallen leaves.

On the Leaves. The first evidence of the disease in the spring is upon the unfolding leaves. The scab spots usually appear first upon the under surface. Later the upper surface becomes infected. Examine the leaves provided and observe:

1. The size, form and character of the spot. The radiating character of the markings of the lesion. To what due?

2. The character of the injury to the leaf. Does the injury show on the surface opposite the spot?

3. Difference in the character of the upper and under surface of the leaf itself. Of the scab spots on the two surfaces of the leaf.

4. The variation in the character of the scab spots on different leaves. Make drawings to show the characters of the scab spots on the upper and under surface of the leaves.

On the Fruit. Where the infection of the calyx is not severe enough to prevent the fruit from setting, the apple as it enlarges shows the enlarging scab spots which become very evident as the season advances. In the young apples provided. Observe:

5. The black scab spots. Their form, size and effect on the fruit. To what region on the apple are they largely confined? Why?

6. The felty black center of the spot. In some cases this felt is gone at the center of the spot, which is hard, of a reddish brown color and often cracked.

7. The papery rim of border of the spot. Best seen in the younger spots. This consists of the cuticle of the apple that had pried loose by the fungus as it spreads out from the center of the spot. Make drawings to show the points brought out in 5, 6 and 7.

Sometimes these spots cause a dwarfing of the apple on the affected side so that they become one sided.

The apple scab is caused by the fungus known as Venturia inequalis. It lives upon the surface of the host

or nearly so, prying off the cuticle and applying its mycelium closely to the host tissue.

Control. One spraying just before and one immediately after blossoming are most important for its control. If the scab is serious it may be necessary to spray a third time. The spray used is known as Bordeaux Mixture. It is made of copper sulfate and lime. Directions for its preparation are given in any of the references in Part V.

68. FIRE BLIGHT.

Materials: Read the experiment. Obtain Cornell University College of Agriculture, Bulletin 272. In sections 5 and 6 obtain specimens at blossoming time and press them. Later in 7 obtain fruit and preserve in a five per cent solution of formalin, to which has been added enough copper sulfate to just color the water. The latter will hold the color in the fruit. Whenever possible fresh material should be used.

This is the most common and best known bacterial disease of plants occurring in this country. It affects apples, pears, quinces and occasionally plums, apricots, and a few ornamental and wild plants related to the apple family. The affected tissues are killed outright.

Symptoms. The symptoms of this disease will be studied in the order in which they manifest themselves during the season on different parts of the tree, beginning with the first activity of the disease in the spring.

The hold-over canker is the source for the first infection in the blossoms in the spring. Typical cankers on the limbs of apple and pear trees have been provided. Study the specimens before you carefully and observe:

1. The smooth, more or less sunken area in the bark, its margin sharply defined by a definite crack in the epidermis—the canker. In active cankers this margin is not sharply defined. Note the diseased spur or shoot at the center of each canker.

2. The margin. Note that it is irregular, the crack being formed by the drying away of the diseased tissue from the healthy when the active progress of the disease was suddenly checked. Dry or cold weather may thus check the spread of the canker. These specimens were taken in the autumn or winter.

3. The surface of the canker. Note that it is smooth, seldom roughened or wrinkled. It is often checked in from the margin by drying. Compare with the healthy bark in this respect. Locate the lenticles.

4. Make a careful drawing of the canker you have studied. Label fully.

These cankers are formed during the summer and early autumn, and in many of them the bacteria pass the winter dormant, or only slightly active in the partially living tissues along the margin. With the increased temperature and rise of sap in the spring, these bacteria become active, spread rapidly into the adjoining healthy tissue, increasing the area of the canker and oozing out through the lenticles to the surface in sticky, milky drops. If active cankers are available make a careful drawing, showing large viscid, milky drops that have oozed out. (See Fig. 16 N. Y. Cornell Bulletin No. 272.)

5. Blossom Blight. Bees and flies visit these active cankers in the spring to feed on exuding sap and then visit the opening blossoms, where they leave behind them some of the blight bacteria with which they are smeared. Here in the nectar and in the injuries made by the insects' claws in the tender tissue of the flower, the bacteria multiply rapidly, killing the blossom. Study the specimen provided or Fig. 6, Cornell Bul. 272. Observe:

6. The dead and blackened flowers. The leaves of the spur are also dead and brown. The bacteria have spread down the pedicles in the spur. The dead and blackened blossom spurs are usually the first striking evidence of the disease in the spring. The oozing cankers

are usually overlooked. Make drawing of a blighted blossom spur.

7. Fruit Blight. Frequently only one blossom on a spur is infected and by the time the bacteria have killed it and worked their way down the pedicle to the spur itself, the uninfected blossoms have developed fruit of a considerable size. From the spur the bacteria now work into the base of these fruit pedicles and by way of them to the growing fruit. Study Fig. 6, Cornell Bul. 272. The curculio and aphids frequently introduce the bacteria into the fruit through their punctures. The disease does not always enter the fruit by the pedicle. Note that the leaves of the spur are also dead and shriveling. In rainy, muggy weather the bacteria ooze from these blighted fruits and blossoms in sticky drops as they do from the hold-over cankers.

8. Twig Blight. The bacteria from the diseased blossoms and fruits are carried by sucking insects to the tips of the growing shoots and waterspouts and are there introduced through the wounds or punctures made by the insects into the tender, succulent tissues. Here they multiply rapidly, killing the shoot, causing the form of the disease commonly known as "Twig Blight." Blighted twigs have been taken from the tree in summer and pressed. Examine the specimen provided and observe:

9. The contrast between the diseased and healthy portions of the twig in both the twig and leaves. You may be able to find the dried ooze. Draw the blighted twig.

10. In some of the specimens note that the dormant buds in the axils of the leaves just below the blighted portion have been prematurely forced. Explain this.

The organism that causes this disease is Bacillus amylovorus. See Fig. 6, Cornell Bul. 272.

11. Control of the Disease. No method of protecting the trees by means of sprays is effective because it is impossible to reach the bacteria. The disease can be effect-

ively controlled by inspecting the orchard at least once a week during the growing season, beginning as soon as the blossoms begin to fall, cutting out the diseased portions and disinfecting the cut surfaces with corrosive sublimate solution made by dissolving one tablet in a pint of water. (See Cornell Bul. 272.) If diseased trees are available see if you can control the disease in this way.

Question: Point out the practical importance of each of the following facts about Fire Blight:

1. It is a bacterial disease.
2. It occurs only in North America.
3. The bacteria causing the disease pass the winter in hold-over cankers in any of its numerous hosts.
4. The bacteria get into the host only through wounds.
5. The chief agents of dissemination are certain insects.
6. The bacteria are usually introduced into the young and growing parts of the host, where in these succulent tissues they multiply and develop the disease very rapidly.

69. THE MOUTH-PARTS OF INSECTS.*

Materials: Lens, needle, forceps, grasshopper, honey bee, squash bug, moth.

Insects that injure plants are of two classes. The distinction between these two classes is in the form of their mouth-parts. One class has its mouth-parts fitted for biting or chewing, while the other class has them fitted for sucking. Methods of destroying insects are based on this difference in the structure of the mouth. Insecticides of one kind are used for killing insects with a mouth fitted for biting. Such insects usually feed upon the leaves of plants. Poisons of different kinds are therefore sprayed or dusted upon the leaves. The poison is taken up by the insect with its food, producing in its ali-

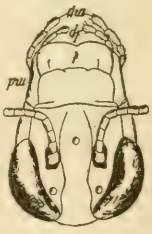


FIG. 12.—*The head of a locust.*

*From Cornell Rural School Leaflet.

mentary canal changes that eventually cause its death. Insecticides of an entirely different kind are used for sucking insects. These insecticides usually contain a resin, alkali, oil, or a strong caustic, which corrodes or contracts and shrivels the body of the insect, covers the breathing pores located along each side of the insect's abdomen, and in this way causes its death.

To determine what kind of insecticide shall be used to destroy any particular kind of insect, it is necessary to determine first what kind of mouth-parts it has. To be able to decide this question accurately, something must be known of the more essential structures of an insect's mouth.

Mouth-parts Fitted for Biting. Observe that the head of an insect may be held either horizontally or vertically; if horizontally, the mouth opening is at the extreme front end of the head; if vertically, the mouth opening is at its lower end on a plane with the under side of the body. The locust or ordinary grasshopper, which has been selected as typical for those insects with biting mouth-parts, holds its head vertically with the mouth opening below. Fig. 12. The locust is especially suitable for study, not only because specimens can be obtained easily, but also because it is truly representative of the biting type of insect.

The locust (grasshopper) mouth-parts consist of seven distinct portions: an upper lip (labrum), two biting jaws (mandibles), two holding jaws (maxillae—singular maxilla), the tongue (hypopharynx), and a lower lip (labium.) The labrum is a movable flap closing the mouth opening in front. Fig. 13. The mandibles, Fig. 13 md, are strong, toothed jaws with sharp edges which move sidewise just behind the labrum and are used for cutting and grinding the food. The maxillae, Fig. 13 mx, are situated just behind the mandibles and like the mandibles move sidewise. Each maxilla bears on its outer end two finger-

like appendages: one the galea, Fig. 13 gl, is more or less spoon-shaped, the other the lacinia, Fig. 13 lc, pointed and with two teeth. The galea and lacinia aid in holding the food in the mouth, where it can be crushed by the mandibles and masticated. Each maxilla also bears on one side a five-segmented feeler or palpus (plural palpi), the maxillary palpus. The hypopharynx is a small tongue-like structure situated in the mouth and attached to the inner surface of the lower lip. Fig. 13 hy. The lower lip or labium, Fig. 13 lb, in the locust and other insects consists of a single piece; it is in reality a pair of jaws similar to the maxillae grown together on the middle line. The labium bears on each side a three-segmented feeler or palpus, the labial palpus, Fig. 13 lp, and at its apex two large, more or less square flaps, the paraglossae, Fig. 13 pg, and at the bottom of the slit between the paraglossae, a minute projection, the glossa, Fig. 13 g. The glossa in the locust is rudimentary, but in many biting insects it is as long as the paraglossae, and, as will be seen later, forms an important part of the mouth of sucking insects. Detach and draw the parts shown in Fig. 13.

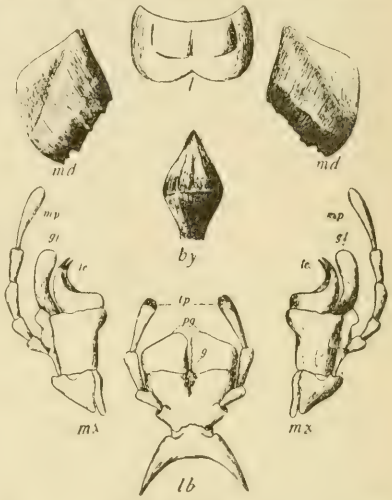


FIG. 13.—*The mouth-parts of a locust. l, labrum; md, mandible; hy, hypopharynx; mx, maxilla; mp, maxillary palpus; gl, galea; lc, lacinia; lb, labium; lp, labial palpi; pg, paraglossae; g, glossa.*

The mouth-parts of the locust illustrate well the form and arrangement of the parts in the mouth of biting in-

sects in general. The biting type is found in cockroaches, locusts, crickets, beetles, caterpillars, and larvae of practically all kinds. Certain beetles, like the plum-curculio, have the front of the head produced into a long snout or proboscis with the mouth-parts at the end of the snout. The mouth-parts of such insects are like those of the locust and are therefore fitted for biting.

Mouth-parts Fitted for Sucking. The mouth-parts of the locust have been described in some detail because the mouth-parts of sucking insects have all been developed by modification of the biting type. These modifications have proceeded in different ways in different groups, and are so characteristic and peculiar for each group that it is possible for the students of insects to recognize the group to which any particular insect belongs by a study of its mouth-parts alone. Bees and wasps have one type; the two-winged flies, as the mosquito, horse-fly, and house-fly, another; the true bugs, as the cicada, stink-bug, and squash-bug, another, and the moths and butterflies still another.

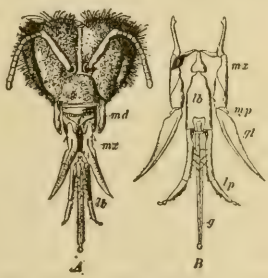


FIG. 14. — *Honey-bee. A, head of honey-bee showing mouth-parts extended; B, maxillae and labium enlarged.*

Bees and Wasps. The mouth-parts of these insects are usually stated to be of the sucking type; they are in reality a combination of the two. Mandibles, Fig. 14 md, with sharp cuttin gedges are usually present and fitted for biting, the upper lip is small and indistinct, the maxillae and labium, Fig. 14 A, have been greatly elongated and find their greatest development in the honey-bee If the maxillae, Fig. 14 mx, of the honey-bee are compared with those of the locust, it is seen that the lacinia is wanting and the maxillary palpus, Fig. 14 mp, is reduced to a mere tubercle. The greatest modification is found in the labium; the glossa, Fig. 14 g, in

the locust a mere rudiment, is longer than any other part, while the paraglossae, large flaps in the locust, are mere rudiments completely concealed by the base of the labial palpi, which like the glossa have been greatly elongated. The maxillae and labial palpi have been hollowed out on one side, and when closely appressed to the glossa form a tube for taking up liquids. Make a drawing of the head of a bee, showing mouth-parts.

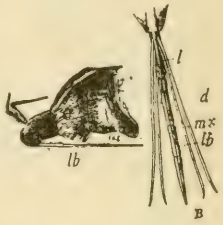


FIG. 15.—*Squash-bug. A, head and thorax viewed from side. B, mouth-parts separated and enlarged.*

True Bugs. The mouth-parts of the true bugs are so different from those of all other insects that there cannot be said to be any resemblance whatsoever. Observe that when the head is examined from the side, Fig. 15, a slender tube is seen extending from the apex of the head along the under side of the body between and beyond the first pair of legs. This tube is the modified labium, Fig. 15 lb. It has a slit on the under side and consists of three or four segments. The slit is triangular in outline near the apex of the head; it is filled by a triangular shaped labrum, Fig. 15 l, which completely closes this part of the tube. Both palpi and paraglossae are lacking. Contained within this tube are four bristle-like structures; two of them represent the greatly modified mandibles, Fig. 15 d, and two of them maxillae, Fig. 15 mx. They are so changed in appearance that their identity was determined only by studying their development. The bristle-like mandibles and maxillae have at their apices fine teeth with which they can puncture the plant, and are usually of about the same length as the tube; but in scale insects, as the San Jose scale, the tube is very short and the bristles are two or three times as long as the body. Make drawing showing these parts.

Moths and Butterflies. The mouth-parts of a moth or butterfly when not in use are almost completely concealed. They are rolled up into a tight spiral like a watch-spring

on the under side of the head, Fig. 16 A. They are not inconspicuous because of their small size, for in the adults of many of the larger Sphinx moths they are nearly six inches long, but are concealed by the flattened scales which cover the body. The upper lip or labrum is reduced to a mere rudiment, the mandibles or biting jaws are wanting, the lower lip or labium is represented by the labial palpi, Fig. 16 lp, which are rigid and project up over and in front of the face. The coiled tube consists of the two maxillae, which have been greatly elongated and closely appressed to each other. Each maxilla is hollowed out or grooved on its inner surface, Fig. 16 C, and by the close apposition of these grooves a tube is formed through which liquid food can be drawn. Moths and butterflies obtain their food in great part from the nectar cups of flowers. In some moths the tips of the maxillae are armed with strong spines, with which they can lacerate the tissues of ripe fruits and set free their juices. Make drawings of the head of a moth as shown in Fig. 16 A and B.

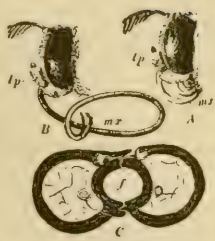


FIG. 16.— *Moth. A, head with maxillae slightly uncoiled. B, head with maxillae uncoiled and the two maxillae separated at apex. C, cross section of maxillae to show the furrow, f, formed by their appression.*

The insecticidal poisons applied for biting insects have no effect therefore upon sucking insects, because the sucking insects puncture the plant tissue and feed upon the juices of the plant beneath the poisonous coating on the surface. Since the poison cannot be taken up with their food, it is not carried into their alimentary canal, and its application produces no changes in their life.

INSECTS WITH BITING MOUTH-PARTS:

Grasshopper-like Insects:

Crickets, katydids, meadow grasshoppers, locusts or grasshoppers.

Beetles:

June bug or May beetle, Colorado potato beetle, lady bug, click beetle, flat-headed appletree borer, firefly, rosebug, striped cucumber beetle, cucumber flea beetle, pea weevil, blister beetle, plum curculio.

Larvae:

Larvae of beetles (grubs), larvae (caterpillars) of moths and butterflies, larvae of saw-flies.

INSECTS WITH SUCKING MOUTH-PARTS:

True Bugs:

Four-lined-leaf-bug, red-bug, bed-bug, chinch-bug, squash-bug, stink-bug, cicada, leaf hopper, aphids or plant lice, pear-tree psylla, San José scale.

Moths and Butterflies:

Codling moth, bud-moth, clothes-moth (larvae have biting mouth-parts), peach tree borer moth (larvae have biting mouth-parts), canker-worm moth, measuring-worm moth, cut-worm moth, tomato-worm moth, Cecropia moth, Polyphemus moth, Luna moth, tent caterpillar moth, Cabbage butterfly, Monarch butterfly, Viceroy butterfly, Red Admiral butterfly, Mourning Cloak butterfly.

Adults of two-winged flies:

Mosquito, black fly, horse fly, syrphus fly, bot fly, house fly, horn fly, blow fly.

Bees and Wasps:

Yellow jacket, hornet, carpenter bee, bumble bee, leaf cutter bee, honey bee.

Of the insecticides chief among the poisons are Paris Green and arsenate of lead. Among the contact remedies lime, sulphur and tobacco. Obtain without cost the third reference "Destructive Insects and Their Control" and experiment with one each of the two classes of insects found destructive to vegetation in your region. Every experiment station publishes literature on the control of insects within its State so that it is possible to obtain definite information about almost any destructive insect.

PART VI. TESTING MILK AND ITS PRODUCT.

70. EXPERIMENTS WITH MILK.

Materials: Milk, microscope, litmus paper, rennet, two evaporating dishes, dilute acetic acid.

(a) Examine a drop of milk with a microscope. Make a drawing.

(b) Test the reaction of milk with litmus paper.

(c) (1) Warm some milk in a test tube to a temperature of the body (98° F.) and add a few drops of rennet. A curd of casein is soon formed.

2. Repeat (1), but boil the rennet first. What effect does boiling have on the rennet or enzyme?

(d) Place 20 c.c. water in an evaporating dish and 20 c.c. milk in another evaporating dish. Heat both equally near the fire to boiling. Which boils first? What does this show about the boiling point of milk compared to that of water? Notice the scum which formed on the boiled milk. Remove it and heat the milk again. Result? What is the nature of this scum? The formation of this scum is not a true coagulation.

(e) To about 10 c.c. milk add one drop of dilute acetic acid and boil. The casein is coagulated and brings down with it the fat. This is a true coagulation.

71. ANALYSIS OF MILK.

Materials: Milk, 2 beakers, cylinder or large beaker, watch crystal, water bath, acetic acid, filter, filter paper, alcohol, stirring rod, ether, crucible, scales.

(a) 1. Weigh a small beaker, place 50 c.c. of milk in it and weigh again. Subtract and the difference in weight equals the weight of milk taken. Record this weight.

Pour the 50 c.c. of milk into a large beaker or cylinder and add 100 c.c. of distilled water. Rinse out the small beaker with 100 c.c. more of distilled water and add to the beaker or cylinder. Be sure the small beaker is well rinsed. Mix well and while stirring gently, add dilute acetic acid (1-10) drop by drop, until the precipitate stops forming. Test this by transferring a drop of the liquid to a watch crystal, adding a drop of acetic acid. If no precipitate forms, the solution is ready to set aside over night. This precipitate contains casein and fat. Milk sugar and albumen are in the water solution.

2. Filter and remove all the casein after it has set over night and save filtrate. Drain carefully, squeeze out water from the filter paper into filtrate. Transfer this

wet precipitate to a small dry beaker and add 30 c.c. of alcohol and stir. Filter a second time and squeeze filter paper as dry as possible. Transfer the precipitate to another small beaker and add 50 c.c. ether. Heat on a water bath a little warmer than milk warm, ten minutes, stirring constantly. Filter and save both precipitate and filtrate. The precipitate is the casein. Spread open the paper in order for the ether to evaporate and allow it to dry. Place the dried casein in a weighed dish and weigh. The difference in weights equals the weight of casein.

To get the per cent of casein in the milk, divide the weight of the casein multiplied by 100 by the weight of milk taken in the beginning, thus:

$$\frac{\text{grams casein}}{\text{grams milk}} \times 100 = \%\ \text{casein in milk.}$$

The filtrate contains the fat dissolved in ether. Evaporate the ether by placing the beaker over a heated water bath and the fat will be left. Weigh and the difference between weight of beaker plus fat and weight of beaker, equals the weight of fat. Get per cent of fat in milk by dividing the weight of fat multiplied by 100 by the weight of milk taken in the beginning, thus:

$$\frac{\text{grams fat}}{\text{grams milk}} \times 100 = \%\ \text{fat.}$$

The ether dissolved the fat out of the casein. Casein is not soluble in ether.

Go back to the first filtrate (after you filtered off the acetic acid from the casein.) Throw away half the solution or save for a second trial and evaporate the other half over a flame. This contains the water, milk sugar, lactic acid, and albumen. As you heat the solution, note the coagulation of the albumen. When the albumen has coagulated, filter. Evaporate the filtrate to dryness, but do not burn it. Sugar will be left. Test with Fehling's solution. (See Exercise 37, a.) Does the milk sugar crystalize readily?

(b) To find per cent of solids and ash in milk. Weigh 5 c.c. milk in an evaporating dish. Evaporate it over the flame carefully, taking care not to blacken it, as

some carbon would be consumed as carbon dioxid. Finish evaporating in a water bath, then heat in an oven at 100° C. or 212° F. for fifteen minutes. Cool and weigh. Place again in the oven for fifteen minutes. Cool and weigh, and if the two weights are the same, get per cent by dividing the weight of the milk after water is evaporated out by the weight of the milk taken. The result will be the per cent of total solids in the milk. What is the per cent of water? Transfer to a clean crucible and place over a flame and burn off the organic material. Burn until the ash is perfectly white. Cool and weigh. Divide the weight of the ash by the weight of milk taken and the result is the per cent of ash in the milk. This ash contains the mineral salts. Save for the next experiment.

72. TESTS FOR THE MINERAL SALTS IN THE ASH OF MILK.

Sodium and Potassium. Treat 1-3 the ash of milk obtained in the previous experiment with 10 c.c. distilled water. Filter and test 1-3 the filtrate with litmus to see if it is neutral. Dip a platinum wire in this 1-3 and test for potassium and sodium in the flame. Use purple glass for potassium as in the presence of sodium, potassium cannot be seen.

Chlorids. Test the second portion of the distilled water solution for chlorids by acidifying with a few drops of nitric acid, and adding one drop of silver nitrate solution. A white cloudiness shows chlorids.

Iron. To the remainder of the distilled water solution add a few drops of hydrochloric acid. Add a few drops of potassium ferrocyanid. Let stand a few minutes. A blue color shows iron.

Calcium and Magnesium. Take the second portion of ash and add 10 c.c. warm hydrochloric acid. Note if any gas is given off. If so carbonates are present. To the hydrochloric acid solution, add ammonium hydroxid until alkalin. (Test with litmus.) Add an equal amount of ammonium oxalate and heat to boiling. A white precipitate shows the presence of calcium. Filter this and

to the filtrate add a little acid sodium phosphate. A white precipitate shows magnesium.

Phosphates. To the remainder of the ash add nitric acid until acid and add twice its volume of ammonium molybdate solution. Allow to stand. A fine yellow precipitate or color shows phosphates. Place in a table the minerals found in milk.

73. CALIBRATION OR CORRECTION OF GLASSWARE.

Materials: Mercury, scales, milk, and cream test bottles.

The correctness of the graduation of glassware may be most conveniently and accurately tested by the following method:

(a) **Milk Test Bottles.** Weigh 27.10 grams of mercury into a perfectly clean and dry milk test bottle. Since the specific gravity of mercury is 13.55 or 1 c.c. weighs 13.55 grams, double this weight will occupy a volume of exactly 2 c.c. Close the neck of the milk test bottle with a small, smooth, soft cork, or a wad of absorbent cotton cut off square at one end. Press this stopper down to the first line of the graduation, then invert the bottle so that the mercury will run into its neck. If the total space included between 0 and 10 marks is just filled by the 2 c.c. of mercury, the graduation is correct.

The mercury may be conveniently transferred from one test bottle to another by means of a thin rubber tube which is slipped over the ends of both bottles and one weighing of mercury will thus suffice for a number of calibrations.

Mercury may be cleaned from mechanical impurities, dust, water, etc., by filtration through heavy filter paper. This is folded in the usual way, placed in an ordinary glass funnel and its point perforated with a couple of pin holes. The mercury will pass through in fine streams, leaving the impurities on the filter paper.

(b) **Cream Test Bottles.** The cream test bottles may be calibrated by the method given for milk bottles. The

neck of a cream bottle that measures fifty per cent fat will hold 10 c.c. or 135.5 grams of mercury.

(c) Pipette and Acid Cylinder. In calibrating the pipette sufficiently accurate results may be obtained by weighing the quantity of water which the pipette will deliver, viz., 17.5 grams. A measureful of water may be emptied into a small vessel, weighed, and this vessel weighed a second time. The weight of the water contained in the pipette is the difference.

Calibration of the acid cylinder is not necessary since small variation in the amount of acid measured out does not affect the accuracy of the test. In calibrating any of the glassware water instead of mercury may be used, but is less satisfactory and not in such general use.

74. DETERMINATION OF THE STRENGTH OR SPECIFIC GRAVITY OF SULPHURIC ACID.

Materials: Milk test bottle, scales, sulphuric acid to be used in the Babcock test, acid hydrometer (See b.)

(a) Weigh a dry test bottle and then fill with acid exactly to the zero mark. Weigh again accurately and the difference between the two weights will give the weight of the acid. Empty the bottle and thoroughly rinse with water. Wipe the outside dry. Fill with water to the zero mark as before and weigh. The difference between this weight and that of the empty bottle gives the weight of the water. Calculate the specific gravity by dividing the weight of the acid by the weight of the water. If the quotient is between 1.82 and 1.83 the acid is of correct strength.

If the acid is a little too strong, later in making tests take less than the required amount, perhaps, about 16 c.c. If too weak add a litle more than 17.5 c.c. If the acid is too strong the better way to do is to pour the acid into a bottle containing a small quantity of water. Never dilute sulphuric acid by pouring water into the acid as the acid may be spattered. For more accurate results the temperature of the acid should be 60°F.

(b) A shorter method is by the use of an acid hydrometer. When an instrument of this kind is used it is only necessary to lower it into the acid and read off the specific gravity.

75. THE BABCOCK TEST OF MILK.

Materials: Half pint of milk (enough for entire class), 17.6 c.c. milk pipettes, milk test bottles, water-white sulphuric acid of specific gravity between 1.82 and 1.83. Vessel for heating water, small beaker, dividers, (the latter desirable but not necessary) and Babcock tester, distilled or soft (rain) water.

(a) Sampling the Milk. Be careful that the sample represents a fair average to be tested. Any cream that may rise on the milk should be thoroughly mixed with the milk by cautiously pouring back and forth from one vessel to another.

(b) Measuring Milk. This is done with a milk pipette which holds when filled to the mark on the stem, 17.6 cc. Suck the milk up into the pipette above the mark and place the finger quickly on the upper end of the pipette, then press firmly down to keep the milk from running out. Hold the pipette vertically with the mark on a level with the eye and by gently relaxing the pressure of the finger on the end of the pipette, air is admitted and the milk is allowed to flow slowly out until the top of the column of the milk is level with the mark of the pipette. Read it to the lowest part of the curve or meniscus. The pipette then holds 17.6 cc. of milk.

(c) Filling the Test Bottles. Place the point of the pipette into the mouth of the milk test bottle, holding both milk test botle and pipette in an inclined position. By removing the finger from the end of the pipette the milk will flow out of the pipette and into the bottle.

The object of inclining the test bottle and pipette is to allow the milk to run down the side of the neck of the test bottle, thus allowing the exit of the air in the bottle. If this precaution is not observed, the air will bubble out and cause some of the milk to overflow.

Allow the pipette to drain into the test bottle and blow into the upper end of it to discharge the last drop of milk in the pipette into the test bottle.

The best results will be obtained by having the samples of milk and also the acid at the temperature of 60° F.

Find the ground or frosted part on the body of the bottle and place on it your initials; or better still ask the teacher to give you a number corresponding to a number by the side of one of the receptacles in the tester. Always use the same number and the same bottle in order to avoid confusion.

(d) Adding the Acid. After the milk has been measured into the test bottles, the acid should be added. This may be done at once or the milk may be allowed to stand in the test bottles for a number of days without changing the results. Fill the acid measure up to the mark (17.5 c.c.) with sulphuric acid of the specific gravity between 1.82 and 1.83. To pour the acid into the test bottle, the bottle should be placed in an inclined position so that the acid will flow down the side of the test bottle and not drop through the body of the milk in the bottle. By observing this precaution, charring of the milk is avoided and also spilling out of the acid. If the acid has been properly added, there will be distinct layers of acid and milk in the test bottle, without any black layers mixed between them.

(e) Mixing the Milk and Acid. This is done by giving the test bottle a combined rotary and shaking motion, being careful not to allow any curd to get into the neck of the bottle. The shaking of the bottle should be continued until all the particles or clots of curd are entirely dissolved. The liquid will then be a dark brown color and of a high temperature, due to the chemical action of the acid on the milk. The object of adding the acid is to dissolve all the solids in the milk, except the fat which is left in suspension in the liquid.

Caution. The acid is very corrosive and should not be allowed to get upon the person or clothes. If any

should be spilled on the skin or clothing, it should be quickly washed off with water. Color can be restored to clothing by treating the spot at once with ammonia water.

(f) Whirling the Bottles. Place the test bottles with the milk and acid properly mixed in the tester or centrifugal machine. The bottles should be arranged in pairs at the opposite side of the center, so that they will balance when rotating. It is better to put the bottles into a tester directly after mixing the milk and acid, while the bottles are hot. If, however, this should not be convenient, the bottles may be allowed to stand an indefinite period, but when they are placed in the machine, means should be provided for heating them while rotating so as to keep the fat in a melted condition. This is done in the steam machine by turning on a steam jet provided for that purpose or in the hand machine by placing boiling water in the bottom of the tester and putting on the cover at once to retain the steam. The bottles should be whirled for five minutes at the speed marked on the machine, and then the machine allowed to slowly come to rest for the purpose of adding hot water.

(g) Adding Hot Water. The object of adding hot water is to bring the fat up into the graduated portion of the neck where it can be measured. Boiling hot water should be added by means of the pipette or a beaker. Perfectly clear readings can be insured by adding the water in two installments. First, add enough hot water to bring the fat to, but not into, the neck of the bottle, then whirl for two minutes. Stop, and add enough hot water to bring the fat into the graduated part of the neck, adding the water gradually so as not to overflow the fat. Whirl a third time for one minute. With this method a beautifully clear reading should result with a layer of clear water below the fat. If the reading of the fat is at all cloudy add a little hot water and whirl again. It is desirable to use distilled water, rain water, or soft water of any kind.

(h) Reading the Test. The fat, if the bottles have been kept at a proper temperature, will be liquid and will be level or right angled to the neck of the bottle at the ends of the fat column. To read the per cent fat, hold the bottle up with the fat on the level with the eye and read the graduations at each end of the column of fat. Make a liberal reading by including the upper and lower meniscus in the reading. Each small division represents two tenths of one per cent of fat and the large spaces numbered 1, 2, 3, etc., to 10, represent one per cent of fat each. By subtracting the readings taken, the percentage of fat is obtained. Thus if the top of the fat column is at 7.4 and the bottom at 2.6 the reading is 7.4 less 2.6 equals 4.8 per cent fat, which means that in 100 lbs. of milk there are 4.8 lbs. of fat. The reading may be more easily done by using a pair of dividers.

(i) Washing the Test Bottles. This is done most easily if the bottles are emptied at once after making the test and while hot. They should be given a rotary motion which allows the air to enter and empties them quicker, besides carrying off the sediment that is on the bottom of the bottles. Rinse thoroughly with boiling water to remove the grease, dirt, and acid solution from the inside. Occasionally boil the bottles in water containing a little cleaning powder.

76. THE BABCOCK TEST OF CREAM.

Materials: Babcock tester and accompanying apparatus, cream, two fifty per cent test bottles.

In testing cream inaccurate results will be obtained if 17.6 c.c. cream is measured out in a pipette as in the case of milk. In the first place the specific gravity of cream is lower than that of milk. The specific gravity of 20% cream will be considerably more than 40% cream. Also cream will adhere more to the sides of the pipette than milk. Hence accurate tests of cream can only be made by weighing the cream in the Babcock test bottle.

Place a cream test bottle on each side of the scales and see that they are accurately balanced. Place 18

grams in weights on one side. Take the sample of cream to be tested and warm it by shaking the cream and vessel in a pail of water as hot as the hand will bear for one or two minutes. (The cream should not rise above 90° F). Mix by pouring from one bottle to another four or five times. Suck up the cream into the milk pipette until the upper level is an inch or so above the 17.6 c.c. mark. Gradually let it run into one of the bottles until the scales just balance. Remove the weights, leave both bottles on, and in a similar manner pour cream from the same sample, or another sample to be tested, into the empty bottle on the other side until the scales just balance. Add the acid and complete the test the same as for milk.

Unless the reading is done quickly the bottles should be placed in water from 140° to 150° F., the water rising nearly to the top of the necks. Let them remain there five minutes, then perfectly clear readings can be obtained. This is necessary when several samples are to be tested by one operater, as the fat will contract from the cold and slip down the neck before all can be read.

77. THE BABCOCK TEST OF SKIM MILK.

Materials: Skim milk bottle, 17.6 cc. pipette, acid cylinder, sulphuric acid, half pint of separator skim milk.

The Babcock test of skim milk, butter milk, and whey is the same as that of milk except as indicated in this experiment.

A double necked test bottle is made especially for measuring small amounts of fat. The smaller neck will measure .25 of one per cent, each of the smaller graduations representing .01 of one per cent.

To make a test measure out 17.6 c.c. of skim milk with a pipette as was done with milk and then pour it into the larger neck of the skim milk bottle. Next slowly add the sulphuric acid, but instead of using 17.5 c.c. of acid use 20 c.c. Place in the tester with the filling tube toward the center. Whirl and add water in the usual manner, but it is highly desirable to use either distilled or

rain water. Make a liberal reading as in the case of milk. Some difficulty may be encountered in getting the smaller amount of fat within the scale. This may be overcome by putting a cork into the neck of the large opening and gently working it up and down so that it will be possible to regulate the position of the fat. Make a reading as quickly as possible or the fat may adhere to the inside of the neck as a film of grease which cannot be measured by the scale. A test of .02 of one per cent shows an efficient separation.

A test of skim milk showing no fat in the neck of the test bottle on completion of the test generally shows poor work on the part of the operator and should be repeated.

Obtain some butter milk and also some whey and test each the same as skim milk except that in the case of whey 17.5 c.c. of acid is sufficient since whey contains less solids not fat for the acid to dissolve.

78. THE LACTOMETER AND ITS APPLICATION.

Materials: Quevenne lactometer, 500 c.c. cylinder, pint of milk, pint of skim milk.

The specific gravity of normal cow's milk will vary in different samples between 1.029 and 1.035 at 60 degrees F., the average being about 1.032. The lactometer is used for determining the specific gravity of milk. There are two in use: the Quevenne and the Board of Health. Only the Quevenne will be considered.

The Quevenne lactometer consists of a hollow cylinder weighted by means of mercury so that it will float in milk in an upright position, and provided with a narrow stem at its upper end, inside of which is found a graduated paper scale. A thermometer is placed in the cylinder with its bulb at the lower end of the lactometer and its stem rising above the lactometer scale. The scale is marked at 15 and 40, and divided into 25 equal parts, with figures at each five divisions of the scale. The single divisions are called degrees. The fifteen degree mark is placed at the point to which the lactometer will sink when lowered into a liquid of a specific gravity of 1.015

and the 40 degree mark at the point to which it will sink when placed in a liquid of a specific gravity of 1.040. To mix thoroughly pour the sample to be tested from one receptacle to another then fill a 250 c.c. or larger cylinder about three fourths full. Carefully lower the lactometer into the cylinder until it floats. In about half a minute take the lactometer reading and the temperature reading. In reading the lactometer degrees the mark on the scale plainly visible through the upper portion of the meniscus should be noted. When the lactometer degree is known, the corresponding specific gravity is found by dividing by 1000 and adding one to the quotent.

Example: If the lactometer reading is 34.3 and the temperature 60°, the specific gravity is 34.3÷1000=.0343; .0343 plus 1=1.0343.

Like most liquids milk will expand on being warmed, and the same volume will weigh less when warm than before; i. e., its specific gravity will be decreased. Therefore the lactometer is standardized to 60°. It is inconvenient to always have milk at exactly this temperature. By making a temperature correction milk between 50° and 70° may be tested, but outside of a range of 10° on either side of 60° the test will be inaccurate. To make the temperature correction add .1 to the lactometer reading for each degree above 60°F., and subtract .1 for each degree below 60°; e.g., if the reading at 63° is 33.6 it will be 33.6 plus .3=33.9 at 60°. The specific gravity would then be 33.9 divided by 1000=.0339. .0339 plus 1=1.0339. If the reading is 30 at 54° the corrected reading will be 30—.6=29.4.

Test the specific gravity of a sample of skim milk and of a sample of milk with a small amount of water added.

Question: 1. Under what conditions would it be difficult to detect adulteration with water?

2. When could the presence of water be easily detected?

79. TESTING THE ACIDITY OR SOURNESS OF MILK AND CREAM.

Materials: Samples of milk and cream, 50 c.c. burette* provided with stopcock, 17.6 c.c. pipette, a tin, porcelain or glass cup, ½ gallon neutralizer, indicator.

With a 17.6 c.c. pipette measure into a clean cup this amount of milk and add a few drops of indicator. Attach the burette to a ring stand and fill with the alkali solution nearly to zero mark. Read accurately the top of the column. Next cautiously add the neutralizer from the burette. By constant stirring during the operation it will be noticed that the pink color formed by the addition of even a drop of alkali will at first entirely disappear, but as more and more of the acid in the sample becomes neutralized, the color will disappear more slowly, until finally a point is reached when the pink color remains permanent for a time. No more alkali should be added after the first appearance of a uniform pink color in the sample. Take a second reading of the column. Ascertain the amount of alkali solution used by subtracting the readings of the scale on the burette. The per cent of acidity may be obtained by dividing the number of c.c. used by 20. The result will be the per cent of acidity in tenths. For example if 17.6 c.c. of milk required 3 c.c. of alkali solution to give a pink color the per cent of acid is 8÷20=.4%.

80. CALCULATION OF THE PERCENTAGE OF MILK SOLIDS.

Materials: One or two pint samples of milk, cylinder, lacometer, Babcock tester and accompanying materials.

The calculation of milk solids can be easily done by using the following formulas:

Per cent of Solids not fat=¼L+.2f.

Per cent of Total Solids=¼L+1.2f.

*In the Marshall Acid Test the per cent acidity can be read directly. If no burette is at hand the outfit for this test had better be purchased.

L being the lactometer reading at 60°F or corrected for temperature, and f the per cent of fat in the milk.

Example. If the lactometer reading (L) is 31.2, the temperature (T) is 64° and the per cent of fat (f) is 3.6 the calculation of Solids not fat is as follows: 31.2+.4=31.6, the corrected lactometer reading, adding .1 for every degree over 60°.

Per cent of solids not fat=¼L+.2f,
=¼x31.6+.2x3.6
=7.9+.72=8.62%

Per cent total solids =¼L+1.2f,
=7.9+4.32=12.22%

Or for per cent of total solids simply add the fat to the solids not fat as 8.62+3.6=12.22.

81. TEST FOR PHYSICAL ADULTERATION OF MILK.

Materials: Lacometer, Babcock tester, normal, watered, skimmed, and watered-and-skimmed milk.

Milk may be adulterated by being watered, skimmed, or both watered and skimmed.

If the analysis of the suspected sample shows

sp. gr. of milk	low	watered
fat and solids not fat	low	watered
sp. gr. of solids	normal	watered
sp. gr. of milk and of solids	high	skimmed
solids not fat	high	skimmed
fat and solids	low	skimmed
sp. gr. of milk	normal	watered and skimmed
sp. gr. of solids	normal or high	watered and skimmed
fat and solids not fat	low	watered and skimmed

Latitude of variation.

Specific gravity of milk may vary from 1.029 to 1.035.

Fat must not fall below 3.

Solids not fat must not fall below 9. (in most states.)

Specific gravity of solids may vary between 1.25 and 1.34.

The specific gravity of (milk) solids is determined by the following formula: $S=\frac{t}{t-\frac{100s-100}{s}}$

S being the specific gravity of the milk solids, s that of the milk and t the total solids of the milk.

Example: A sample of milk has been found to contain 13. per cent of total solids, sp. gr. 1.032; then $\frac{100s-100}{s}=\frac{100\text{x}1.032-100}{1.032}=3.101$; t—this or 13.—3.101 =9.899; then dividing t by this, $\frac{13.}{9.899}=1.31$, the specific gravity of milk solids. Let the teacher furnish samples of normal, watered, skimmed and watered-and-skimmed milk and the class determine each.

82. TEST FOR CHEMICAL ADULTERATION OF MILK.

Materials: Salicylic acid, formalin in samples of milk, ether, surphuric acid, alcohol, iron chlorid solution, hydrochloric acid, evaporating dish.

(a) Salicylic Acid. To 20 c.c. of milk add from 2 to 3 c.c. sulphuric acid and 4 to 5 c.c. ether and stir in an evaporating dish. Evaporate and treat the residue with about 3 c.c. alcohol, add a few drops of iron chlorid solution and heat again. A deep violet color will be obtained in the presence of salicylic acid.

(b) Formalin (Formaldehyde). To one-fourth test tube of milk add an equal volume of water and 5 to 10 c.c. sulphuric acid used in testing. A violet ring is formed at the junction of the two liquids if formalin is present; if not, a slight greenish tinge will be seen. The violet color is not obtained with milk containing over .05 per cent formalin.

(c) Formalin (optional).

To 10 c.c. of milk in an evaporating dish add an equal volume of hydrochloric acid. Add one drop of ferric chlorid solution, heat gently, stirring until contents are nearly boiling. The formaldehyde turns the casein of the milk violet. If no formalin is present the liquid turns brown only.

83. DETERMINATION OF MOISTURE IN BUTTER.

Materials: 300 c.c. aluminum cup, butter to be tested, ring stand, spatula or spoon, fine wire or thread, scales, alcohol lamp.

Anyone who is familiar with testing of butter for moisture is well aware of the fact that an accurate test is not possible unless the sample taken for testing is a representative one. In view of the heavy penalties imposed because of excessive moisture, no buttermaker can afford to do the work ignorantly or carelessly. The matter of proper ways of taking samples and of testing is as yet more or less unsettled, but the following suggestions are generally recognized as being worthy of attention.

In taking a sample from the churn, remove a portion of the surface of the butter at vairous places of the churn, and by means of a spatula or spoon take out small pieces. Butter in the churn contains many water pockets and these must be avoided, as they are worked out in packing.

In taking a sample from the print use a fine wire or thread as butter can be easily cut in this way. Several small slices from different parts of the print are sufficient. As fast as the slices are made, place them in an ordinary pint fruit jar and after they are all in it, screw the cap down air-tight.

Samples taken as above are approximate representatives only, so that in order that the parts taken may become a uniform mixture, it is necessary that they be melted at as low a temperature as possible (not above 120° F.) in order that none of the volatile substances pass off as vapor. This may be done by placing the sealed sample in a pail of water as hot as the hand will bear and

allowing it to remain there a few moments, shaking occasionally, until the butter is melted. Cool until solid, shaking often to insure an even distribution of the constituents.

Special scales for moisture testing are on the market, but any sensitive scales will do.

See that the scales are accurately balanced. The aluminum cup is capable of taking up moisture from the air and for this reason must be heated a moment or two until perfectly dry and at once accurately weighed. When the scales balance with the beaker on, write down the weight of the beaker and then place a 10 gram weight on the side opposite the beaker.

Take the sample of butter, remove the cover, and with a spoon place butter in the beaker until the scales exactly balance, giving a ten gram sample.

Heat the sample until all the moisture is evaporated. A direct flame as that of an alcohol lamp is satisfactory, but care must be taken not to burn the butter. By shaking two or three times with a rotary motion, the burning of the butter may be prevented.

After sputtering has ceased, weigh. Heat a second time and if the weights are the same upon reweighing, all the moisture has been driven off. If the two weights are not the same, heat the third time and weigh again and continue to reheat and reweigh until a constant weight is obtained.

Record results and calculate the per cent of moisture as follows:

Weight of beaker	38.5 grams
Weight of beaker and butter	48.5 grams
Weight of beaker and butter after heating	47. grams
Weight of butter after heat	8.5 grams
Loss 10—8.5	1.5 grams

$(1.5 \div 10) \times 100 = 15\%$ moisture in the sample. It is illegal to sell butter containing more than 16% moisture.

84. DETERMINATION OF SALT IN BUTTER.

Materials: Burette with stopcock, white cup, saturated solution of potassium dichromate, silver nitrate solution made by adding 14.531 grams of silver nitrate to 1000 c.c. of distilled water. Butter to be tested, small bottle with cork or cover, 250 c.c. Florence flask with the 250 c.c. height marked with a file.

Melt about two ounces by guess of butter in a small covered bottle as was done in testing for moisture. Weigh into the Florence flask exactly ten grams of the melted sample, then add enough rain water of a temperature of about 140° F. to make 250 c.c. Shake thoroughly several times to dissolve the salt. Take 25 c.c. (best obtained with a 25 c.c. pipette) of the brine solution thus prepared, place it in the cup and add 2 or 3 drops of potassium dichromate as an indicator.

Place the silver nitrate solution in a bruette arranged as in testing for the acidity of milk. Gradually let it run into the cup until a permanent pink color remains upon being thoroughly stirred. Note the number of c.c. of silver nitrate used. Divide this number by the factor 2. The result is the per cent of salt in the sample. As salt is much cheaper than butter fat it is to the advantage of the butter maker to add about as much as the market will bear. Three per cent may not be too much.

85. DETERMINATION OF THE PER CENT OF FAT IN ICE CREAM.

Materials: Glacial acetic acid, sulphuric acid, ice cream, Babcock tester, and milk test bottle.

Weigh nine grams of the melted sample into a Babcock milk bottle. Fill almost to the neck with a mixture of glacial acetic acid and sulphuric acid, using equal volumes of each. Heat a few minutes until black, then whirl in the tester for five minutes. Add water to bring the fat column within the graduation of the neck as in the regular Babcock test. The reading multiplied by two gives the per cent of fat in the ice cream since the bottle is graduated for 18 grams and only 9 grams were used.

If sulphuric acid alone is used it is likely to char the sugar in the ice cream, thus giving difficulty in reading the results.

Ice cream should contain not less than twelve per cent of milk fat.

Fruit ice cream and nut ice cream should contain not less than ten per cent of milk fat.

86. STANDARDIZATION OF MILK AND OF CREAM.

Materials: Half gallon of milk testing 4% or over, 1½ quarts of skim milk, Babcock tester and accompanying materials.

Milk or cream is "standardized" or brought to any required test by the addition of skim milk, milk, or cream, according to the conditions. Standardization is perhaps most often a lowering of the butter fat test to just meet the requirements imposed by law.

The ordinance of the city of Los Angeles requires at least 3.5 per cent butter fat. Probably most of the milk **produced** for Los Angeles consumption will test 4% or more.

Example. Standardize 300 pounds of 4% milk to 3.5%, using skim milk testing .1%.

300 lbs. of 4		3.4*	300 : 3.4
	3.5	Then	as
X lbs. of .1		.5	X : .5

Solving, 300:3.4::X:.5
3.4X=150
X=44.1

*The 3.4 and .5 are obtained by subtracting diagonally.

Therefore to get the standard of 3.5% we must add 44.1 lbs. of skim milk.

Proof: 300 lbs. of 4% milk=12 lbs. of fat.
44.1 lbs. of .1% skim milk=.04 lbs. of fat.
344.1 lbs. of 3.5% milk=12.04 lbs. of fat.

Obtain a half gallon of milk testing 4% or over and a half gallon of skim milk. Test each for butter fat.

Weigh the milk. Calculate the number of pounds of skim milk that must be added to bring the milk to the standard of 3.5%. (Figure on a test of 3.6 since it is unsafe to risk selling milk at exactly the standard as some of the milk delivered may fall below.) Add the calculated amount of skim milk, then test the standardized milk to see if it tests 3.6.

REFERENCES FOR CLASS STUDY.

The first books in the list for each part will be found more satisfactory for high school work.

Parts I and II

Fletcher, S. W.—Soils.
Snyder, H. S.—Soils and Firtilizers.
King, F. F.—The Soil.
Roberts, I. P.—Fertility of the Land.
Voorhees, E. B.—Fertilizers.
Hopkins, C. G.—Soil Fertility and Permanent Agriculture.
Hilgard—Soils.
The Soil Bulletins of the U. S. Department of Agriculture.
Bailey, L. H.—Cyclopedia of American Agriculture.

Part III

Snyder, H. S.—Chemistry of Plant and Animal Life.
Bailey, E. H. S.—Sanitary and Applied Chemistry.
Snyder, H. S.—Chemistry of Plants.
Bulletins of the U. S. Department of Agriculture.

Part IV

Wickson, E. J.—California Fruits and How to Grow Them.
Bailey, L. H.—Principles of Fruit Growing.
Warren, G. F.—Elements of Agriculture.
Waugh, F. A.—Systematic Pomology.
Hume, H. H.—Citrus Fruits and Their Culture.
Lodeman, E. G.—Spraying Plants.
Osterhout, W. J. V.—Experiments with Plants.

Bailey, L. H.—Pruning Book, Horticulturists' Rule Book, Nursery Book.

Bulletins of the U. S. D. A.

Part V

Warren, G. F.—Elements of Agriculture.

Bulletin 218, California Plant Diseases, Agricultural Experiment Station, Berkeley, Cal.

Destructive Insects and Their Control—Cal. State Board of Horticulture, Sacramento, Cal.

Duggar, B. M.—Fungous Diseases of Plants.

Part VI

Wing, A. H.—Milk and Its Products.

Farrington and Woll—Testing Milk and Its Products.

Van Slyke—Testing Milk.

Van Norman, H. E.—First Lessons in Dairying.

Bulletins of the U. S. D. A.

Manual

of

General Agriculture

EDWARD P. TERRY